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EUROPEAN SCIENTIFIC NOTES, VOLUME 32, NUMBER 4,(U)
APR 78 A W PRYCE, V S HEWITSON

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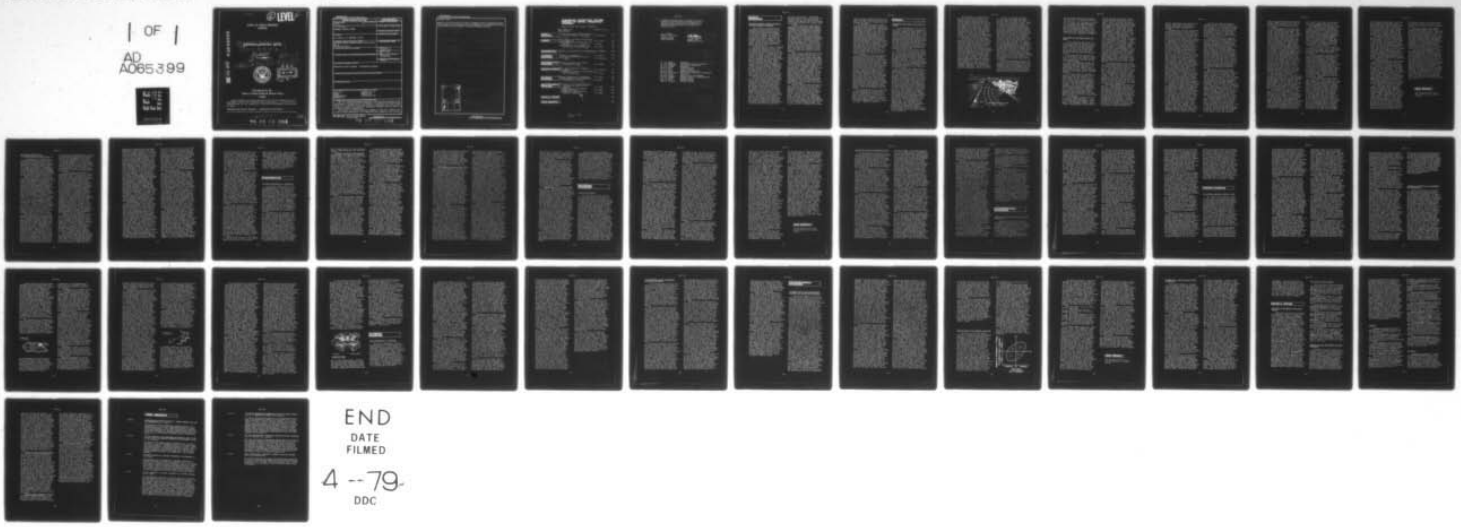

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OFFICE OF NAVAL RESEARCH
LONDON

(6) EUROPEAN SCIENTIFIC NOTES.
Volume 32, Number 4,

(14) ESN 32-4
(11) 30 April 1978
(12) 43 p.

(10) Aubrey W. Pryce Victoria S. Hewitson

Distributed by the
Office of Naval Research Branch Office,
London

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ESN 32-4	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EUROPEAN SCIENTIFIC NOTES		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) A.W. PRYCE & V.S. HEWITSON, editors		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Office of Naval Research Branch Office London Box 39 FPO New York 09510		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 30 April 1978
		13. NUMBER OF PAGES 36
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

EARTH SCI
ENERGY
ENGINEERING SCI
MATERIAL SCI
MATHEMATICAL SCI
PHYSICAL SCI
PSYCHOLOGICAL SCI

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is a monthly publication presenting brief articles concerning recent developments in European Scientific Research. It is hoped that these articles (which do not constitute part of the scientific literature) may prove of value to American scientists by disclosing interesting information well in advance of the usual scientific publications.

The articles are written primarily by members of the staff of ONRL, with certain articles prepared by, or in cooperation with, members of the scientific

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S/N 0102-014-6601

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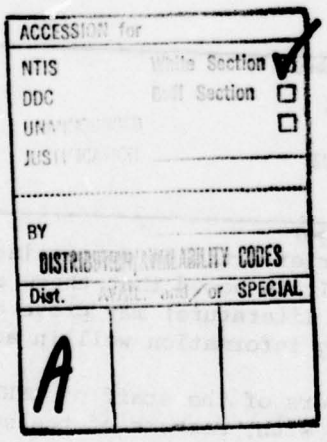

EUROPEAN SCIENTIFIC NOTES
OFFICE OF NAVAL RESEARCH
LONDON

Aubrey W. Pryce and Victoria S. Hewitson

30 April 1978 Volume 32, No. 4

Contents:

European Scientific Notes is a Class I Periodical prepared and distributed by the Office of Naval Research London in accordance with NAVEXOS-P-35. Prepared and submitted by the scientific and technical staff.

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EARTH SCIENCES

OVERVIEW OF REMOTE SENSING PROGRAM IN THE USSR ACADEMY OF SCIENCES

One of the very interesting and informative papers presented at the International Conference on Earth Observation from Space and Management of Planetary Resources was a summary of the Soviet Academy of Sciences' remote sensing program. The paper was presented by a senior member of the Academy, Professor A.P. Kapitza, and treated remote sensing studies, experiments, results of various programs, and current Soviet objectives in the remote sensing field.

The Conference was held in Toulouse, the areospace capital of France, from 6-11 March and attended by over 500 representatives from some 30 countries. The topics covered, in addition to technology and science, included space law, economic and the social and political aspects of remote sensing. The Conference was organized by the European Space Agency (ESA) and the French Centre National d'Etudes Spatiales (CNES). It was sponsored by the Parliamentary Assembly of the Council of Europe, the Commission of the European Communities and the European Association of Remote Sensing Laboratories. The intent of the meeting was to survey the results of remote sensing over the past few years, cover the basic scientific problems related to these new disciplines, and present future plans and programs.

The Kapitza paper adhered rather well to the intent presenting a history of the Soviet remote sensing program, remote sensing techniques utilized, a review of satellite and aircraft experiments, and the philosophy behind the overall remote sensing program. The Academy of Sciences' program was initiated in 1969 and over 30 member institutions are now involved. The member institutions primarily include civil national laboratories and universities. The Soviets are studying technical principles of remote sensing, optical and radiometric methods of remote sensing, methods and algorithms for computer processing of multiband videodata, and methods of interpretation and use of data for scientific and practical applications. Experiments are being carried out from aircraft, unmanned satellites, and orbital space stations over special test sites typical of the main landscape and climatic zones of the USSR.

Initial spacecraft remote sensing experiments were aimed at developing techniques of multiband remote sensing utilizing spectrophotometric equipment designed at the Leningrad State University. These experiments were used to: identify agricultural crops and their states of growth; study the processes and degree of soil salination; determine the composition of geological formations; single out local structures promising to the discovery of oil, natural gas and important minerals; study the relief of sea, lake and river shoals, bottom deposits and aquatic vegetation; detect water pollution and transport of sediment; and detect air pollution and the aerosol and moisture content of the atmosphere.

These initial experiments have been continued on manned orbital space stations and also aircraft with the resulting development of a sophisticated multiband "space camera" known as the MKF-6 and a multiband "synthesizing projector" known as the MAP-4. Both have been used to demonstrate successfully remote sensing in six selected narrow bands of the visible and near infrared regions of the spectrum. The MKF-6 camera has been employed, for example, to study the Caspian Sea from the standpoint of the shapes of shoal bottom reliefs, the ancient dendritic beds of rivers, and underwater bars and accumulative crests. Kapitza presented a number of most interesting slides of Caspian Sea images obtained utilizing the camera/projector arrangement. In particular geomorphological signatures and water-land interfaces were evident.

Optical scanning remote sensing systems have been installed on the Soviet Meteor meteorological satellites to investigate the efficiency of optical systems in solving scientific, methodological, and economic problems requiring fast delivery of survey data to earth. Specific areas of interest include hydrology, forestry, agrometeorology and oceanology. The ocean images have been used successfully for some time by the fishing industry and marine fleet to select optimal shipping routes, determine periods for maximum fish catches,

and warn ships of impending weather hazards. Ice maps based on satellite data are used to study ice vortexes and ice moisture phenomena.

In the area of microwave remote sensing, passive radiometry experiments have been carried out from aircraft and satellites to investigate: sea-surface temperature and state; sea salinity; soil moisture content; potential fire areas; bogs and peat piles; and the characteristics and boundaries of sea and lake ice and mountainous glaciers. Other radiometric measurements have included determination of atmospheric water-vapor content, cloud water-droplet content, atmospheric temperature profile, and the state of packed-ice fields. The Antarctic sea-ice limits have been measured, and its floating and packed ice regions have been outlined. Although not mentioned in the paper, it can be assumed that such sea-ice measurements have also been made in the Arctic regions.

In the area of remote sensing data handling, the Soviets are developing special purpose software to digitize multiband video information and analyze these data in short time periods. During the question period, Kapitza brought out the fact that data processing and improvement of detector resolution were the prime targets of future studies rather than the launching of more satellites. The Soviets appear to have the same problem as everyone else in the remote sensing business—that is how to best handle the vast amounts of data being received. They are attempting to work out a philosophy for processing and utilization. The process of "thematic" data processing has been proposed to this end, with the development of dynamic system models to predict such events as crop seeding periods, stages of vegetation diseases, optimum harvest times, ice movements, and sea states.

The entire paper is to be published in the proceedings of the Conference and will contain more details with regard to satellite and aircraft experiments that have been carried out as well as the Soviet approach to data handling and analysis, albeit no details on specific equipment utilized to obtain such data. (Robert W. Rostron)

ENERGY

THE "WATER LENS" MAKES A BIG SPLASH IN NORWAY

In the September 1977 issue of *ESN* (31-9:365), we reported on an embryonic Norwegian research project aimed at attempting to design a "water lens." This project was the brain child of Dr. Even Mehlum of the Central Institute for Industrial Research (CIIR) in Oslo. The earlier article reported on how Mehlum's mathematical analysis of nonlinear waves had led to the successful design of a new type of acoustic lens as well as a new and comparatively inexpensive infrared lens, both of which are now under further development and refinement by Norwegian private firms.

The purpose of the present article is to report that the previously embryonic "water lens" project is now the focus of considerable international interest and Norwegian government funding. The embryo has hatched into a quite healthy fledgling. In brief, recent experiments carried out in a large wave-making test tank in Trondheim have demonstrated that, as the mathematical theory and computer simulations carried out at CIIR had predicted, water waves can be made to focus.

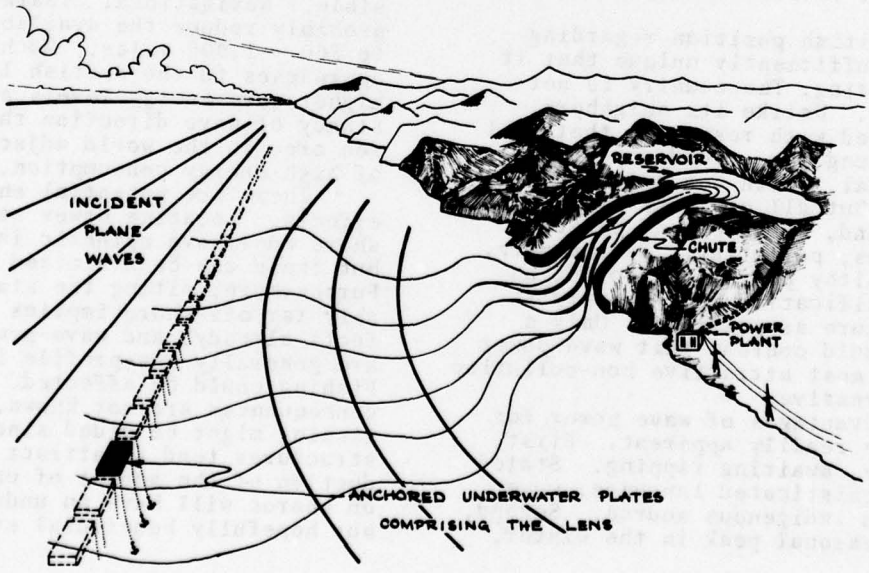
It is obvious that ocean swells contain a great deal of energy, and many researchers world wide are exploring various practical techniques to extract it. The North Atlantic in particular provides an abundant source of untapped energy; according to recent years' measurements, the average energy contained in the swells coming in from the North Atlantic to the coasts of Europe is between 20 to 80 MW/km. What apparently is unique about the Norwegian approach to wave-energy extraction is the notion of first concentrating the wave energy and, in a sense, tapping it from a single point. In contrast, for example, the widely publicized British "Salter duck" research program aims to capture wave energy by the reciprocating motion of "ducks" which are anchored to the ocean floor and bob up and down as the wave passes. As Mehlum and his colleagues, Drs. F.S. Ljunggren and J. Stames, point out, the idea of first concentrating water energy represents nothing new in electrical energy production—hydroelectric plants are built at huge reservoirs where the water has collected, not at each small stream in the mountains.

The principle of a water lens is the same as that of an optical one; namely, it must have the property of transforming an incoming plane wave into an outgoing spherical one converging toward the focal point of the lens. By analogy, it is clear that a water lens should have the ability to retard some parts of the wave front relative to other parts so that, after passage "through" the lens, the incident wave, with crests parallel to the lens, emerges as a wave with (approximately) circular crests centered at and converging toward the desired focal point.

In addition, a water lens should have the properties of minimum energy reflection, minimum sensitivity to wave direction (since the main wave direction may change significantly from one storm to another), and should be designed to operate efficiently over a certain spread in wave frequency around the mean frequency. For a given geographical area, measurements of the statistical distribution of frequency and direction of the swells would be necessary in order to design the optimum lens for that location. The task of optimum water-lens design is mathematically comparable to that of optical lens design, i.e., one must solve the relevant wave equation (differential equation) subject to the appropriate boundary conditions. Not an easy problem; but, according to Mehlum, soluble.

In order to actually construct a water lens, the Norwegians exploit the well-known fact that the speed, and hence the wavelength, of water waves increases with increasing depth. Thus, a structure consisting of a number of plates positioned horizontally and at different depths below the surface would have the desired focusing effect. Preliminary mathematical design considerations indicate that the nominal plate depth should be about 30 m in order to cause most of the energy contained in the swells along a several kilometer stretch of shoreline to be concentrated within an area of less than 500 m. In this focus area, the wave will crest to a considerable height. A proposed energy tapping method which is suitable for the Norwegian coast is to construct a large funnel-shaped chute which the focused wave would enter, pumping itself upward into a reservoir as high as perhaps 100 m above sea level. (See illustration.) Estimates based on experiments carried out at Trondheim indicate that 70/80% of the kinetic energy of the concentrated wave at sea level would be captured as potential energy in the reservoir.

Although experiments to date have confirmed theoretical expectations, more and larger-scale experiments are to be conducted this year to measure, and subsequently compare with theoretical predictions, the rate at which lens efficiency deteriorates when wave frequency and/or direction vary from the norm.



Several million dollars have already been allocated for further research on the water lens. If the theory is borne out by actual ocean experimentation, it is estimated that even in Norway—where hydroelectric power is about the only inexpensive commodity to be found—the production of electricity via a water-lens system will be cost-competitive with conventional hydroelectric facilities. (William J. Gordon)

WAVE POWER, UK—BRITANNIA RULES THE WAVES

The traveler who has chosen to ferry from England to France, or vice versa, knows that the waters surrounding the British Isles are capped by waves. In fact, the fiercest waves are on the other side of the Isles, the western shores, particularly in Scotland. Why not put these waves to work?

The harnessing of wave power is not a particularly new concept. What seems to be new is the degree of interest and commitment, and some refreshingly novel schemes.

This note summarizes briefly the philosophy that motivates British research in harnessing wave power, the ingredients in their program, and a mere outline of the schemes being examined and developed. A more detailed account will be forthcoming in an ONRL Report.

The British position regarding energy is sufficiently unique that it bears repeating. The country is not energy-poor. Unlike its neighbors, it is blessed with resources that will carry it along for extended periods of time—coal, North Sea oil, nuclear reactors. But all of these are non-renewable and, to an extent based on one's biases, polluting. Furthermore, it is a healthy policy to provide as much diversification in a country's energy picture as possible. Only a minority would contest that wave power offers the most attractive non-polluting power alternative.

The advantages of wave power for Britain are readily apparent. First, it is there, awaiting tapping. Stated in more sophisticated language, wave power is an indigenous source. Second, it has a seasonal peak in the winter, closely matching the British demand-pattern for electrical power; this is contrary to the situation for solar power. Third, wave-power systems can (and almost certainly would) be modular and, therefore, less vulnerable to major damage. Any damage that is sustained is likely to be minor to the entire system. Fourth, wave systems are inherently simple, certainly in comparison to nuclear reactors. This seems to imply a reduced level of design, operation, and maintenance. Fifth, to repeat, wave power is essentially non-polluting. Sixth, it appears to be financially competitive. This last feature has two aspects. A total wave system, of a given power capacity, competes well with a nuclear system of equal power. In addition, wave-power systems, being modular, entail less initial capital investment. This last feature carries through to demonstration considerations. Wave-power schemes can be tested with relatively minimal investment. And this is in sharp contrast with a competing water-based power scheme—tidal power—also under consideration in Britain. Tidal barrages (dams) cannot be built piecemeal.

The estimated annual wave energy on a 1,700-mile contour, 10 miles from the shore around Great Britain, is about 5×10^8 MW-h (mean power level of 21 kW/m). This is more than twice the current total annual energy output in the UK. Ringing Great Britain is not feasible. Navigational clearways would probably reduce the available contour to 500 - 1,000 miles. Much of the wave approaches to the British Isles have higher wave-energy levels and more constancy of wave direction than any other sea area in the world adjacent to areas of high-energy consumption.

There are potential environmental effects. Locating power stations off-shore must have esthetic implications, but these can be minimized in design. Furthermore, siting the stations reasonably far off-shore implies minimal effects already, and wave-power stations are generally low-profile installations. Fishing could be affected. The full consequences are not known. Indeed, fishing might be aided since floating structures tend to attract fish. Reduction of the amount of wave incidence on shores will have an undetermined, but hopefully beneficial effect on

erosion, deposition, and sea-water turbidity. Calm shore waters will be greeted differently by individuals, depending on their commitment to surfing.

Although more than 340 wave-energy systems were patented in Britain between 1856 and 1973, current attention is restricted largely to four main candidates and a few other possible ones. In fact, it was the early success of one of these front-runners that is greatly responsible for the renewed interest in wave power. This token belongs to Prof. Stephen H. Salter (Univ. of Edinburgh) whose "ducks" inevitably come to mind when wave power is discussed (see H. Herman, "The University of Edinburgh Materials Engineering Research On the Land and Sea" *ESN* 29-11:472). As Salter tells it, he was down with the flu in September 1973 and was told by his wife to "stop lying there looking sorry for yourself. Why don't you solve the energy crisis?" Salter's duck is a truly streamlined flap, which is urged in one direction by the passing waves, but returns to its normal position without any appreciable resistance in its water environment. To achieve this, Salter has designed the front of the vane (i.e., the section that encounters the greatest portion of the wave crest) as a modified flap, while the base of the duck is circular. A power station unit would consist of a string of some 10 - 20 ducks mounted coaxially for about one km. The diameter of the cylindrical potion of the duck would be 10 - 20 m. The duck strings would be moored at a distance of about 10 km offshore.

Salter's current testing is limited to an impressive water-tank system in his laboratory, equipped with appropriate water-wave drives and controls to generate a wide variety of potential sea conditions. The efficiency claimed for the ducks is very promising—85 to 90% of the wave power is extracted by reasonably well-tuned ducks. Even if the compliance of the ducks is far out of tune, the efficiency remains a most respectable 70%. The effects of this high efficiency make for an extremely impressive display; large and even wild waves impinge on the ducks, yet the water behind the duck remains almost entirely placid. I was equally impressed with the enthusiasm of Salter and the students working with him. A jolly good show, indeed.

The ducks convert wave power to mechanical power. Salter intends to proceed next to an oil hydraulic system and, finally, to an electrical turbine. Each conversion step is characterized by high efficiency. The next step in development is a test in Loch Ness, using $\frac{1}{4}$-scale modeling. There seems to be no fear of an encounter with the monster of Loch Ness!

Probably the two major problems associated with the Salter scheme are the considerations of operational lifetime in a maritime environment (e.g., mechanical integrity of a reasonably involved mechanical system over a long time period) and mooring expenses. With respect to the former, Salter points to the use of established mechanical components and the assurances of those familiar with sea-operations. Mooring, according to Salter, should present little more than a 5% component of the total cost; this figure is at variance with estimates that I received in visits to other wave-power centers where estimates of 30%, or even greater are made. In fact, one evaluation is that the mooring problems pose the single largest financial consideration of the entire wave-power program in Britain.

The reader will easily discern my admiration for the Salter scheme. Yet, if I were to make a wager on which scheme is likely to become the front-runner eventually, I would place the Salter ducks second, or even third, among the four current leaders. First place I would award to the scheme being investigated at the National Engineering Laboratory (East Kilbride, Glasgow, Scotland). My visit there was conducted by Mr. Robert Meir. The NEL "oscillating water column" method is based on a well-established approach exploited by Y. Masuda in Japan. The application there is in self-powered buoys. My designation of this method for front-runner agrees with an evaluation made by the Wave Energy Steering Committee, Harwell.

The usual description of the NEL water column compares it with an empty beer can held with its open end under water. As waves flow by, the water level inside the can rises and falls. As the waves pass, the rising water level in the can will force the reservoir of air at the top of the column through a turbine. With the addition of appropriate valves, etc., the air column can be made to drive the turbine in

both up- and down-stroke and to guard against complete extinction of the air column by the invasion of sea water in its place in the presence of very large waves.

The development of the NEL water column is distinctly less mature than in the case of the Salter ducks. Original testing took place with a simple column, then proceeded to more realistically shaped ones, meanwhile preserving the basic concept of a tube. It was discovered, both empirically and theoretically, that the length of the tube is important in achieving high conversion efficiency. Then a quite critical discovery was made, derived in large part from an appreciation of the importance of the peculiar shape in Salter's ducks. NEL went from regular columns to asymmetric columns. The ultimate in this development entails a front wall, whose depth below water level is still highly important (as it relates to wave amplitude), and a parallel back wall that is very long. In fact, one concept is that the back wall would be firmly moored to the sea bottom. By "tuning" these lengths, particularly at the front, as well as the separation between walls (the analogue of the tube diameter), it is possible to achieve close to 100% conversion efficiency for waves of a particular frequency and very high efficiencies for a wide band of waves in the more realistic situation.

The efficiency of the NEL water column is a prime factor in its strength. In addition, there are no large external moving parts and only a few moving parts are in contact with the water. The scheme lends itself to relatively easy maintenance (e.g., removing the flotsam that finds its way into the columns) and simple positioning of adjunct equipment. The dimensions of a unit would be, for example, 30 m × 25 m × 100 m.

The conversion scheme that is best known, after the Salter duck, is the Cockerell raft scheme. Its prominence owes much to the fame of its originator, Sir Christopher Cockerell, the inventor of the hovercraft. The scheme entails trains of several rafts connected by hinges that allow the motion of individual rafts to respond to the local wave profile and takes advantage of the differential motion of adjacent rafts to drive a mechanical conversion device. The "principle" of asymmetry has intruded here as well; the lengths of the rafts in a train, measured in terms of the typical wavelength, might be 1:1:2:1.

Development of the Cockerell rafts is under the direction of Wavepower Limited, a Southampton-based engineering consulting firm in which Sir Christopher Cockerell is a substantial partner. My discussion here was with Mr. J. MacGuire in the Cadnam (Southampton) office; the water tank developments take place at British Hovercraft on the Isle of Wight, some 30 miles away. Actual maritime testing is conducted in the waterways between the Isle and the mainland. The National Maritime Institute is also involved.

In the current 1/10-scale model, a typical raft size is 5 m × 10 m, with a 5-m spacing between rafts. The trains are short; two hinges are reputed to provide as much as 95% efficiency in conversion.

With the possible exception of the hinges, the Cockerell rafts appear to offer the advantage of simplicity in design and construction. Mooring is a very major consideration. Another concern I heard expressed centered on the effects of raft break-up in a strong storm, and the resultant havoc that could result from trains placed close to each other, to optimize power capture. The extent of the mooring problem may be judged by the attention being paid to mooring ropes. (Incidentally, excellent research on ropes is conducted at the NEL). Polyester ropes are currently being employed.

The Salter ducks and the Cockerell rafts are similar in the sense that each concept is a "wave-riding" one (however, significant portions of the wave energy are present below the surface). The NEL column is different in conception, and the fourth major scheme—the Russell rectifier—is also. The rectifier, conceived by Dr. Robert Russell (Director of the Hydraulics Research Station, Wallingford) is essentially a sea-borne dam. The man in charge of the development project, and my host at Wallingford, is Mr. Peter Rance. In this scheme, a structure consisting of a series of high and low level reservoirs is exposed to waves. The reservoirs are separated from the seawater by a set of vertical flaps. Half of these flaps, anticipated to be about 1 m wide and 5 m high, open the upper reservoir to the crest of wave fronts,

for reservoir replenishment, then close at the approach of the wave trough. Water spills over from the upper reservoir to the lower one, driving a turbine for electric power. The excess water delivered to the lower reservoir is released to the sea again through a second set of flaps, opened to the sea near wave troughs but closed near the wave-crest portion of the period.

Of the four major candidates, the Russell rectifier is the least funded and developed. Testing is restricted to low activity levels in a water tank at the Station. An advantage of the scheme is that the rectifier is fixed to the sea bed, minimizing mooring problems. The electrical system can be rather more simple than in other schemes, since the dam spillways can be interconnected; this should minimize the number of turbines involved and provide a steady electrical service without substantial additional smoothing techniques. Flotsam maintenance is simple; screens placed in front of the rectifier units should suffice.

The maximum efficiency anticipated in the rectifier scheme is about 70%, somewhat lower than others, but this is conversion of wave-power to electrical. Efficiency of about 30% has been obtained in the laboratory. The major problem, outside of financial, relates to the flaps. Ideally, the flaps should respond instantly to signals to open and close and require zero force in their motion. They must withstand many cycles without fatigue. At this point, rubber (possibly with metal-fiber reinforcement), a material widely used in maritime applications, is the favorite, but materials selection is a major consideration in the Station program.

In addition to these four major schemes, two others merit mention. Professor Michael French (Lancaster Univ.) has suggested the "inflatable sausage" scheme; his group has received a small amount of funding to test the concept. Here a long inflated bag (sausage), divided internally into smaller compartments, is held at right angles to the incoming waves. As the waves travel over the sausage, they squash the air out of each compartment and, eventually, this air drives a turbine. By using non-return valves, air is readmitted after the passage of the wave crest. In its air handling concepts, the French sausage is similar to the NEL column; in disposition with respect to the wave fronts, it is more closely related to the Salter ducks and Cockerell rafts.

Finally, a group at the Vickers Aircraft Establishment have proposed a drastically different idea. They would place the conversion device at the floor of the sea, very close to the coast. The waves that are tapped in this scheme are the return-ebb waves. These conversion units would be fully submerged at all times, avoiding potential problems that may arise from exposure to air-water interfaces. It would seem that this scheme loses the esthetic advantages shared by the others, wherein the conversion systems are located so far from shore as to be effectively invisible.

The British are committed to reviewing their wave-power programs in 1979 and deciding the directions and extent of their commitment. I anticipate that these programs will receive an enthusiastic reception at that time. Many of the reasons for this were cited earlier. A fuller report on wave-power in the UK, which will follow, will go into these and other details in considerably greater extent. But there is one feature of wave-power that makes it almost a compulsory ingredient in the British energy program: the opportunities and developments are so strongly British in character that it would be hard not to seize this opportunity, even if it were only to enhance prestige and the national image. In fact, it is much more than that. (A. Sosin, Univ. of Utah, Salt Lake City 84112)

ONRL REPORTS

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MORE ENERGY FROM THE SEA?
"...And Why the Sea is Boiling Hot..."

As pointed out in the previous article exploration of methods of obtaining energy from the ocean waves has become a central thrust in the UK's search for alternative energy sources. This topic was discussed once again in a paper presented by I. Glendenning of the Central Electricity Generating Board's Marchwood Eng. Labs., Southampton, at the Energy from the Sea Session of the Oceanology International 78 Conference held in Brighton on 10 March.

While there would be no point in re-covering the details of the various experimental approaches covered by Sosin, some of Glendenning's other points are worthy of attention. Particularly so as the Session was organized by the influential Watt Committee on Energy which has an important UK advisory role across the whole face of the energy field, and since Glendenning's paper was obviously presented from the viewpoint of a national electricity supplier. His brief introductory comments on a number of the alternative sources reflect this. *"Solar energy is economical only in small units....Wind energy density is too low"*—Although he seemed to have some second thoughts on this. *"Geothermal energy is of doubtful value to the UK.... "Tidal energy can handle only 10% of the present national demand."* But, *"Average wave power exceeds the present electrical system capability."* Interest in wave energy then is in its potential technical feasibility and economic viability as a major source.

Important aspects as far as individual wave power units are concerned include optimization of individual unit size that must be tuned to the correct wave frequency, and power rating. One needs on the one hand very high output efficiency for small wave inputs and on the other, system durability at very high wave loadings. Unfortunately, while the waves are the source of the required energy, they are also the destructive force. Substantial data is available on average wave power in the oceans, or has been deduced, but wave power is an extremely variable resource both in the long and short terms, and in spectral composition. Even during winter periods field data from the Atlantic show continuous periods of many days with low power—when, of course, the UK would be in greatest need. Again, individual wave spectra differ significantly. For considered device design and response estimation at a given site, wave information is required in considerable detail. It is also needed to estimate output power and for consideration of methods of power distribution. Current absence of such information for prospective sites is a major limitation on device optimization and economic assessment.

A second series of problems is associated with power take-off, storage, and transmission. A major issue is the avoidance of both electrical and mechanical over-rating and under-utilization. The electrical problem may be eased as one will be using a distribution of small power sources, which will permit some averaging, and the building in of overload safeguards, but the mechanical problem is critically dependent on a true prediction of the highest wave loadings to be expected over an extended period. Structural integrity and enplantment or mooring provide a further series of problem areas. In practice large structures will almost certainly be used to group and integrate a number of individual wave-activated power units, which will in turn be grouped to constitute the next level of the system complex. Damage to or mechanical failure of one unit in such circumstances can easily lead to progressive destruction. Finally the design must provide access for maintenance, cleansing against biological fouling, and replacement of faulty components, all of which will be essential.

Despite the wide range of the technical problems facing the large scale use of wave power and which call for a very substantial R&D effort, Glendenning concluded that research to date suggests technical and possible economic feasibility. However, whether or not wave power will ever be employed at the scale of interest to the CEGB and presumably to the Dept. of Energy, who are funding much of the current research, is another matter dependent on a wide variety of considerations.

The second UK paper at the meeting was concerned with the important problem of energy storage which becomes increasingly important as one moves away from fossil fuels. The approach presented by P.A. Back and I.P. Haigh (Sir Alexander Gibb & Ptnrs) was that of using

hydroelectric pumped storage and power generation, which offers a cycle efficiency of 70% but with the sea as either the lower or upper reservoir. The first requires suitable terrain close to the coast and all too often appears to lead to sites for the upper reservoirs renowned for their unspoilt beauty. The second visualizes use of disused deep mines for the lower reservoir, principally coal, but also including the Cumbrian haematite mines. The broad criteria adapted by Back & Haigh for identifying acceptable sites were a minimum plant installation of 600 MW, an upper reservoir within 1 mile of the sea, and a minimum head of 100 m (200 m for the nearer future). For underground reservoirs the requirement is a void of 4 million cubic meters at 500-m depth. Both weekly and daily pumping and generating cycles were mentioned. The first requires a substantially large storage volume to take advantage of additional storage over the weekend, the second, 30% greater pumping than generating capacity. Storage systems can also be designed to provide fault protection for the grid as at the CECB's Llanberis installation in N. Wales where protection of 1300 MW is available in 10 seconds. It would appear that such storage schemes are particularly suitable for use with nuclear plants to assure maximum benefit from their generating capacity. Glendenning doubted their appropriateness to wave power.

Both UK papers were in a sense concerned with longer term energy-from-the-sea speculations. The three other contributions at the Session appeared nearer at hand and, in fact in one instance was already here. This given by H. Andre (Groupement Régional Production Hydraulique de Savoie, France) was a review of 10 years' experience with the Tidal Power Plant situated in the La Rance Estuary behind St. Malo on the French coast. This system, built between 1961 and '67, incorporates a dam 750-m long at a position of 13.5-m peak tidal range and stores 184 million cubic meters of water. The tide is utilized in a two-way cycle as the turbines installed in each of the 24 individual 10-MW bulb-sets, each in its own bay, can run with the flow in either direction. Generally considered to have reached design expectations, overall energy production reached 507 GWh at La Rance in 1974, but fell to 438 GWh in 1976 when some sets had become inoperative for repair, but rose to 462 GWh in 1977. The most serious problem experienced has been associated with the stators. It had its origin in unexpectedly high electrodynamic forces during asynchronous starting which resulted in mechanical failure of screws holding the stators to the machine frames. Other defects have included difficulties with shaft seals, some rapid corrosion of metal parts (since counteracted by cathodic protection), and loss of insulation by the settling of carbon dust from worn brushes. Although there have been some cracks, the civil engineering work has stood up well.

Environmental impact at La Rance appears to have been minimal, indeed the dam has produced a large expanse of relatively calm water and has been accompanied by a substantial increase in water traffic in the estuary. Commenting on other tidal schemes, Andre noted the probable technical and economic feasibility of the French Chausey Islands or St. Michael's Mount scheme, but indicated questioning of its completion on account of size and construction time (10 years). In this respect it is perhaps in a similar position to the long discussed Severn Barrage Scheme in the UK, variants of which have suggested 4,700- to more than 20,000-GWh annual output, but the development of which appears to fall on economic arguments and the long development and construction times (Exploitation of Tidal Power in the Severn Estuary, *Select Committee on Science & Technology*, HMSO, 28 July 1977, 70p). Much of the technology required, however, would appear to be well on the way in "La Rance."

Returning to wave power T. Miyasaki and Y. Musuda (Japanese Marine Science & Technology Center) reported on work initiated in 1974 that has led through model tests to a many-chambered wave-power buoy of ship-like form. Masuda was previously the originator of the self-powered Whistle Buoy, reputed to be the only current successful application of wave power and which is being used worldwide in situations where electrical power storage is a difficulty. A prototype 500-ton wave-power buoy, the KAIMEI, 800 m long of 12-m beam and 5-m depth has been built and will be tested in the open sea in 40-m water, 3 km off Yura in NW Japan from August '78 through March '79. In principle, KAIMEI is purely a series of appropriately spaced chambers, with some devoted to buoyancy

and others open to the sea below, that act as air-pump rooms driven by the ocean waves. Above each pair of pump rooms is an air turbine-generation unit rated at 125 kW (200 kW max) driven by air flow using a two-valve mechanism designed for constant flow. Theoretical calculations based on comparison with model tests provide an estimate of KAIMEI's air-output power at 4 MW for a 3-m high wave of 7-sec period. (For a 200 m long, 30-m beam and 10 m high unit this becomes 54 MW for a 6-m wave of 11-sec period.)

The remaining contribution to the Energy Session was given by R.D. Fuller (Lockheed Missile & Space Co) who discussed ocean thermal-energy conversion (OTEC), describing the status of the US program and a system configuration resulting from a Lockheed study. Operation is based on the Rankine cycle using warm, ocean surface water and deep cold water as the heat source and coolant, respectively, and ammonia as the working fluid. A temperature difference of 35-40° F is generally considered desirable to make OTEC worthwhile, and while the warm water pick up is from the near surface, the cold water is taken from as deep as 750 m. Such temperature differentials are limited to latitudes of ±20° so that while OTEC is of interest to the US, it would appear to offer little in the way of a potential input to the UK's long-range picture.

The scale of the OTEC system presented probably typifies the nature of many of the engineering problems to be faced in any large-scale exploitation of energy from the sea whether it be wave generated or otherwise. Net bus-bar power level is 240 MW. The main platform of reinforced concrete is 180 m high and supports a telescopic concrete cold water suction pipe of 40-m o.d. that extends to almost 500 m below the platform. Detachable power modules based on a vertical cylinder 20 m in diameter and approximately 140 m high house the heat exchangers, turbogenerators, pumps, and power conditioning equipment, and can be towed out to site for replacement and installation with the major dimension horizontal and then flipped FLIP style. Mooring and anchoring the whole completes the picture.

Whether wave power is to materialize as a major source in the UK, will clearly depend very heavily on an extended marine technology base. But even before that, there is a little matter of the requirement for substantially greater knowledge of ocean wave characteristics.

Proceedings of the Oceanology International '78 Conference are available from BPS Exhibitions Ltd., 220 Great Portland Street, London W1N 5HH. The total package covering all sessions costs £40.00, however, the session on Energy from the Sea is available at £10.00. (Aubrey W. Pryce)

ENGINEERING

ELECTRICAL ENGINEERING AT BIRMINGHAM

As England's second-largest city. Birmingham owes its position to the Industrial Revolution. Its university, which had its origin in a science college launched in 1872, received its charter in 1900 and became the prototype for the British civic universities, with Joseph Chamberlain as its first chancellor. Ever since that time it has occupied a 125-acre campus in Edgbaston, a pleasant suburb two miles southwest of the center of the city. The latter, too, is now pleasant as a result of recent modernization. Of the University's 8000 students, a quarter are candidates for advanced degrees, and its annual research budget exceeds £3 million ($6 million).

The Department of Electronic and Electrical Engineering, headed by Prof. H.A. Prime, has 230 undergraduate and 60 graduate students along with a teaching staff of 4 professors, 3 readers, 6 senior lecturers, and 15 lecturers as well as 10 research fellows and 7 research associates. Its major research facilities include a Cassegranian antenna with a paraboloidal reflector of 6-m diameter on the roof of the Department's building, a 150-m^3 water tank instrumented for underwater acoustic investigations, and a microelectronics processing facility as well as PDP-9 and PDP-11 computers and a mobile laboratory for field use at a variety of sites. This large Department has a correspondingly broad program of research, which is conducted by five groups. This pro-

gram is supported by a variety of governmental, semigovernmental, and industrial sponsors.

Underwater Acoustics and Instrumentation Group. The largest of research groups is that in underwater sound, whose leading members are Drs. Vernon G. Welsby and Hans O. Berktay. (See F.N. Spiess, "Birmingham Underwater Acoustics: A Report on Progress," *ESN* 29-8:333, Aug. 1975.) It was established in about 1955 and is at present particularly devoted to bottom and subbottom mapping because of their relevance to the exploitation of North Sea oil. For bottom profiling a short pulse is transmitted in a vertical fan beam, and two vertically separated hydrophones are used to compare the phases of the received echoes in order to determine the declination angle. Baffles are introduced to hide the surface from these transducers and thus prevent multipath transmission. In this way, plots of depth versus range have been obtained for a 20-m-deep flooded slate quarry in Scotland up to a range of 110 m. Far-field transducer directivity patterns, including the effects of baffling, are obtained in the 150-m^3 tank by extrapolating several thousand near-field amplitude and phase measurements by means of the fast Fourier transform.

For subbottom profiling, advantage is taken of the nonlinearity of underwater acoustic propagation to generate a narrow 10-kHz beam despite the small size of the transducer carried by the Group's towed, unmanned submersible vehicle, which is stabilized in roll, pitch, and yaw by active control surfaces. The nonlinearity is utilized as suggested by Peter J. Westervelt (Brown Univ.) [*J. Acoust. Soc. Amer.* 22, 319, (1950)] to produce the difference of two exciting frequencies. Although the nonlinearity is small, the interaction of the higher-frequency beams creates a long end-fire source at the difference frequency whose beamwidth is only slightly larger than that of the higher-frequency beams. The Group has obtained a 3° beam at 10 kHz from a 40 × 40 cm transducer excited at 80 and 90 kHz, and they are now working with a 15-cm transducer excited at around 300 kHz, investigating the effect of the bottom sediment upon the nonlinear interaction zone, and using buried hydrophones to study the penetration into the sediment.

Studies of underwater sound propagation are underway to determine the effects on transmitted signals produced by fluctuation in the thermal inhomogeneities of the medium. Companion optical studies of propagation through turbid water are also being made, in which a television system with standard test pattern is being used to provide rapid measurements of the available image resolution and range.

The Group is in addition doing considerable work related to the fishing industry. In this connection a log-periodic planar underwater acoustic receiving array has been developed that provides a constant beamwidth (18° ± 2°) over frequencies from 8 to 60 kHz. The array has a hexagonal core of elements, which is surrounded by hexagonal rings fed through a weighting network that is at present switched manually but is to be replaced by appropriate low-pass filters.

For transmission, mechanical coupling between elements is a problem. Methods for forming arrays with common front and back plates sandwiching separate ceramic elements are under investigation nevertheless, and laminated front covers (made of polymers filled with epoxy resin) are being developed for wideband matching of the elements to the water. Here it has been found useful to include lossy layers in order to broaden the frequency response. The Group has thus been able to build a 500-kHz experimental transducer with a 50% efficiency and a 45% bandwidth.

Also for the fishing industry, and specifically as an aid to fish-stock assessment, echoes from various species of caged individual fish have been studied, and their Doppler signatures have been catalogued, but the identification of fish species through their group behavior has not yet been considered. In addition, a moving-target indicator has been developed that reduces false sightings of fish. Finally, the observation that fish are attracted by the sounds of divers, whose stirring up of the bottom may uncover sources of food, has prompted a search for sounds that may be useful in luring fish.

The Group has several commercial sponsors, and close contact is maintained with industry. One sponsor is now manufacturing a 1-to-2000-kHz admittance-locus plotter developed at Birmingham

for the analysis of transducer resonances. Another (Vickers Oceanics Ltd.) will exploit the Group's nonlinear system that succeeded in penetrating 15 to 20 m into sediment to produce high-definition subbottom profiles. There is, in addition, commercially supported work stemming from a National Coal Board project involving air sonar for the control of coal-cutting machines and conveyor belts.

Radiocommunications and Radar Group. Under the leadership of Prof. E.D.R. Shearman and Dr. Dennis C. Cooper, the Radiocommunications and Radar Group is engaged in research on remote sensing via radiometry and air sonar as well as radiocommunication, antennas, and propagation. Just as the foregoing Group has developed a close working relationship with Ministry of Defence underwater research organizations such as the Admiralty Underwater Weapons Establishment (Portland, Dorset) and the Admiralty Research Laboratory [(now part of the Admiralty Marine Technology Establishment (Teddington, Middlesex)], this Group works closely with the nearby Royal Signals and Radar Establishment (Malvern), two members of whose staff have honorary appointments in the Department. Here again there are contacts with industry, while there is funding from the National Environment Research Council to support work with the Group's weather radar, and still other government agencies support projects related to their own fields.

The 6-m antenna on the roof of the Department's building is used for the mapping and analysis of the rainfall distribution by transmitting 5.6-GHz pulses of 200-kW peak power and introducing an attenuation of the received microwave signal varying with time after transmission to obtain a 60-dB dynamic range. An angular resolution of 0.5° and a 0.5-km range resolution are obtained out to 128 km, and the resulting information is stored digitally on magnetic tape for statistical analysis (e.g., correlation with measured runoff). The resulting information is ultimately intended for flood warning, drainage and catchment improvement, and meterological forecasting, as well as for improved discrimination between ground echoes and those from precipitation. This 6-m dish is shared by a Science Research Council project devoted to the measurement of fading and depolarization (of such signals as the 30-GHz beacon formerly transmitted by the ATS-6 satellite) caused by atmospheric conditions and precipitation.

Other environmental-sensing work of this Group involves the study of over-the-horizon radar techniques in the 3-to-30-MHz band to determine sea states over the North Atlantic. A 300-m-long array on an old airfield at Cricklade, Gloucestershire, consisting of 49 vertical broadband monopoles in front of a reflector screen with 6° beamwidth at 10 MHz, which can be steered over a 60° sector in 2° steps by the centrally controlled mechanical switching of delays in the elements' feeders, has been used to transmit 0.5-msec pulses of 100-kW peak power. A range of 3500 km is obtained via skywave propagation. By utilizing an empirical relation between the wind direction and the ratio of first-order Bragg scattering from advancing and receding water waves, which are separated by spectral analysis of the Doppler shift, it has been found possible to map the wind pattern over the ocean. Although there is a right-left ambiguity about the direction at any one point, it can be resolved by taking account of the continuity of the path of the wind. The emphasis of the over-the-horizon radar investigations is now shifting to groundwave-propagation techniques utilizing the pulses from a 2-MHz Loran-A navigation-system transmitter.

The Group is using air sonar for the detection of low-level air turbulence with the support of the Ministry of Defence and the Civil Aviation Authority. In an earlier version a 12-W 5.5-kHz continuous tone was radiated upward, in turn, by each of three horns, aimed in slightly different directions, and three receiving horns at some distance operated continuously to provide information about the air at the nine intersections of the beams. A fast Fourier transform of the received waveform provided the information on turbulence. Potentially troublesome vortices in the wakes of approaching aircraft at Heathrow were detected by this means —persisting up to 20 sec despite high crosswinds. At present, however, this bistatic arrangement is being replaced by a monostatic configuration with pulsed transmission at the same location as reception, permitting greater portability of the equipment. A 1.3-m paraboloidal reflector is used to obtain beams of 5° to 6° width, but noise limits the

useful range to about 85 m. The equipment is to be delivered to the Royal Aircraft Establishment at Bedford, where it will be used in association with other sensors for turbulence and windshear measurement.

Other environmental studies deal with background noise from the sky, the radio noise spectrum produced by vehicles, and radio propagation within cities. In addition, Government Communication Headquarters, Cheltenham, Gloucestershire, is supporting studies of high-frequency skywave propagation and its effect upon the accuracy with which direction finding can be used—on European short-wave transmitters in this instance. It is hoped that range as well as bearing can be obtained by measuring the curvature of the wavefront after using Doppler analysis of the signals received on three antennas to separate the individual ionospherically propagated modes.

Other Groups. The Group on Computers, Control and Machines under Professor Prime, is involved with computer architecture, array processors, computer languages for electric-network analysis, control hardware and simulation connected with electric traction, and various kinds of control systems, such as that for the Underwater Acoustics Group's towed submersible vehicle. This Group also has support from British Rail for the development of active compensation for railside telephone circuits to reduce the noise due to traction currents.

The Solid-State Electronics Group, under Prof. G.T. Wright, is concerned with bipolar devices, metal-oxide semiconductor devices, Schottky barrier-gate field-effect transistors, BARITT microwave diodes, and integrated circuits. The Group has equipment for microelectronic mask making, photolithography, solid-state diffusion and vacuum deposition, etc. Among its current projects is the exploitation of the applications of the silicon square-law resistor, which has been found to have an accurate parabolic characteristic over a working range of several volts at frequencies up to about 100 MHz.

Finally, the smallest Group, that on Electromagnetism under Dr. T.S.M. Maclean, is concerned with antennas of all sorts—wire, loop, paraboloidal, and active. For this last type it has the support of the Royal Signals and Radar Establishment in Christchurch, Dorset.

The University of Birmingham's Department of Electronic and Electrical Engineering is carrying on a wide range of research for government and industry as well as for academic purposes. Despite the support from those quarters, however, all of the research is open. It may be mentioned in closing that, in addition to this Department, Birmingham has another noteworthy Department of Electrical Engineering—at the 83-year-old University of Aston (chartered as a university in 1966) in the center of the city. This is headed by Professor J.E. Flood, well known for his work in the telecommunication field. (See F.N. Spiess, "Academic Acoustics in Birmingham, Continued," *ESN* 29-9:377, Sept. 1975.) (Nelson M. Blachman)

MATERIAL SCIENCES

DEFECTS IN STUTTGART

The University of Stuttgart was for many years crowded into a series of small buildings in the center of one of Germany's fastest growing cities. A decade or so ago the decision was made to make the giant leap to the suburbs, and a large tract of land was procured for the orderly establishment of the scientific and technical part of the University on the new campus. A majority of this building program is now complete, and many of the departments have moved in. It is sad to report that everyone with whom I talked seems to feel that the new campus is something of a failure. Most of the laboratories and offices are in two large high-rise buildings with a collection of smaller ones surrounding them for lecture rooms, service buildings, and dormitories. The design is not visually stimulating, and the continuing construction makes everything look unfinished. Typical of the lack of concern for people in the planning is the fact that there is now no center for student recreation, no athletic facilities or playing fields, no university cultural program, and no convenient public or university transportation to take students into the city. Some, who have rebelled against the factory

atmosphere, have left. The staff are also dissatisfied. They feel that the individuality of groups and departments is lost by piling them into huge omnibuses of buildings. The final straw is that the elevators often do not work.

Of all the institutions one can think of, it would seem likely that universities would have the largest corporate memory of the conditions leading to a situation that is cohesive, warm, stimulating and satisfying for both staff and students. That wealth of experience however, does not always seem to be tapped in architectural design. Perhaps, indeed, a great deal could be learned about what does or does not work in laboratories and universities just as some acousticians have learned about design of concert halls from their successes and failures. (see p 141, this issue.)

The Physics Department of the University is composed of eight institutes; five are in experimental physics and the others are in theory. Three of the experimental institutes work in solid-state physics and are joined together by special blanket funding support from the Federal Government for an effort entitled "Defect Structure in Solids." The cooperating institutes include those of Professor H. Pick who works in inorganic insulators, Professor H.C. Wolf whose interests lie in transport processes in organic solids, and Professor M. Pilkuhn who studies semiconductor materials. The Federal funding allows the creation of joint service facilities for these groups; these include crystal growth laboratories, a group that supplies liquid helium and other refrigerants, and a central computer installation for data handling and the design of computer-controlled experiments. The cooperating institutes jointly report on work accomplished, and some research effort crosses institute lines, however, the separate authority and responsibility of each institute is maintained. The net result of all of this has been the creation of a very strong center for solid-state research at the University of Stuttgart.

In this note I shall report on the work in Pick's institute. For more than two decades Pick and his institute have led the European effort in the study of defects in inorganic solids—often called color centers. He follows Professor R. Pohl of Göttingen whose institute was famous in the same field; Pick was a student of Pohl. Now in turn, Pick is coming to the end of his academic career and has relinquished some of his outside responsibilities and University duties in an orderly way so that his eventual retirement will be as painless as possible.

The work is subdivided among a number of senior associates. Dr. A. Kessler tends to study defects using experimental tools, such as the measurement of dielectric loss, dc and ac conductivity, and especially thermally stimulated depolarization. In this last method a crystal with dipolar defects is cooled from high to low temperature with a high electric field applied. This tends to freeze the defects in special orientations. If the crystal is slowly warmed, the polarized defects become free and a small external current caused by the reorientation of the defects can be noted. From the temperature dependence the activation energy for binding the defect is known. The height of the peak as a function of added impurities helps to identify the defects. Kessler has recently succeeded in having the experiments both run and analyzed by computer. This has made the analysis of activation energies more reliable since the whole curve of a current peak can be analyzed rather than only its initial rise as has often been the case. In addition he has recently discovered that the transient difference in temperature between the electrode and the sample during the warming must be carefully taken into account. When this is done for CdF_2 doped with Na, for instance, the current peaks take a simple form and the activation energies are lower than earlier reported values. From this data good information for the formation and kinetics of reorientation of Na^+ - anion vacancy complexes now appears to be available.

Defects in NH_4Cl crystals have been studied by all the available techniques. Kessler has worked with undoped materials and crystals to which $NiCl_2$, or NH_3, or H_2O have been added. The picture emerging is that the pure crystals contain Schottky defects, i.e., pairs of positive- and negative-ion vacancies. Ionic transport is probably caused by the breaking up of NH_4 complex into NH_3 + H. The H atom is localized briefly on a Cl to form HCl. Meanwhile the NH_3, which has a low activation energy, may

jump into a nearby positive-ion vacancy thus inducing transport. The cycle is completed by the breakup of the HCl with the H returning once again to the NH_3 to make NH_4. Kessler believes that the strong influence of water vapor on the transport measurements results from disturbance of the chemistry of the surface of the NH_4Cl crystal.

It is well known that pure alkali halides become colored upon irradiation with x-rays or gamma rays. At first the F-center is formed; it consists of an electron trapped at a negative-ion vacancy. As these become more numerous, pairs of F-centers are seen and then triplets. All of these have yielded to study by optical and electron spin resonance techniques (ESR) so that models have been clearly established for some time. At the other end of the exposure range corresponding to very long irradiation, one sees phenomena related to large clustering: Colloids, interstitial platelets, and vacancy bubbles. However, attempts to understand complex centers between these extremes and those arising from interactions with chemical impurities have proved to be extremely difficult. Dr. H.J. Paus has been concerned with Z centers—color centers with nearby chemical impurities such as Ba, Ca, Eu, or La. A considerable number of different kinds of centers can be formed as is evident from the variation in the optical absorption and polarization and the formation properties of the centers. Firm, unambiguous models for these centers have proven to be extraordinarily hard to evolve, however, and this work is coming to an end. Paus is also studying the absorption and luminescence of Tl, Ga, and In in alkali halides. Absorption has been studied by magnetic circular dichroism, and emission studies are being done with pulsed-laser excitation at high intensities. As yet work on these systems, here or elsewhere, has not produced a really clear picture of events in the excited states in which there are both allowed and forbidden transitions with strong John-Teller effects complicating the picture.

Dr. L. Schwan is continuing the long term interest of the institute in ESR and ENDOR (electron nuclear double resonance) studies in general and of the properties of H in alkali halides in particular. His work concentrates on the properties of alkali halides with the addition of SH^-. Under uv irradiation this breaks up into a substitutional S^- ion and an interstitial hydrogen atom that is mobile above 105 K and usually becomes H_2 or disappears. However, the hydrogen atom can be localized near Ca^{2+} or Ag^+ ions and then studied by optical and ESR means.

To study these centers theoretically as well as experimentally, Schwan has devised an approach that he calls the LCAO-MO-Matrix Method for Many Electron Systems. In it he considers, for instance, a KCl cluster composed of $4K^+$ and $4Cl^-$ ions with positions on the corners of a cube as in a real crystal. Using the known Hartree-Fock equations for the wave functions of the free ions, he can compute the energy levels of this cluster which fall into groupings closely resembling that of the energy bands of the full crystal. Into this cluster Schwan introduces the hydrogen atom and again computes the perturbed cluster to see how the energy-level structure is altered. There are no fitting parameters. Using these energy-level results, he is able to understand such different processes as ESR, absorption, emission, and radiation effects. The success of this approach and its simplicity has led Schwan and a young theorist, Dr. R. Bauer, to apply the method to other centers and to improve the approximations involved. They are quite hopeful that this approach will develop theoretical methods of sufficient power and sensitivity to work hand-in-hand with experiment in the development of accurate models of defect centers in solids. If this does indeed prove to be the case, a giant step forward will have been taken. (Clifford C. Klick)

ONRL REPORTS

See the back of this issue for the abstracts of current reports.

THE BELGIAN CENTER FOR CORROSION STUDY

The Centre Belge d'Etude de la Corrosion (CEBELCOR), located on the grounds of the Free University of Brussels, is an interesting and unique operation, dominated by the presence of its founder and director, Marcel Pourbaix. He has recently retired from his position as Professor at the Free University and now devotes full-time efforts to CEBELCOR with a vigor and enthusiasm that belies his 70-odd years.

The organization, established about 1950, is multi-faceted in its goals and services. CEBELCOR's central activity is to provide information and consultation on electrochemistry and corrosion-related subjects, at reduced rates to subscribing members. An annual subscription fee of about $250 provides members the following services: Receipt of all current technical reports published by CEBELCOR, a reduced annual subscription rate for the monthly journal *Corrosion Science* as well as for technical reports and *Corrosion Science* published prior to the membership period, and a reduced fee for consulting services.

Although these services appear somewhat limited in scope, the complexities of corrosion problems, particularly those of an industrial nature, and the vast amount of literature published each year have apparently made them quite attractive. For example, in Belgium alone there are 75 subscribers. In addition, there are 120 members from 29 foreign countries, including 17 from the US. They are drawn from such diverse sources as universities, government laboratories, and companies producing chemicals, foodstuffs, metals, appliances, building materials, etc., in testimony to the ubiquitous presence of corrosion. The use of these services by developing countries, such as Algeria, Ivory Coast, and Panama, is cited as being particularly valuable as it provides them with a source of sophisticated, technological information not readily available through other channels.

Besides the above activities, Pourbaix and his associates offer a range of other technological services such as seminars and short courses, either on-site or at CEBELCOR; problem-solving; and facilities and expertise for contract research of both a fundamental and applied nature. These are provided through a subsidiary organization, "The Commission for Fundamental Studies and Applications" (CEFA), organized in about 1969, the Belgian section of a joint activity with the Department of Metallurgical and Materials Engineering at the University of Florida at Gainesville under the title, "Center for Applied Thermodynamics and Corrosion." The stated goal of the combined organization is to facilitate and coordinate research efforts in the affiliated institutions on scientific and engineering problems of national and international importance in the field of corrosion. The two groups bring together a wide range of expertise in electrochemical thermodynamics and kinetics, and in electron optical instrumentation to be used for studying and characterizing corrosion reactions and products. While the cooperative efforts are still ongoing, budgetary and staffing problems have slowed the joint center's development. Many such noble endeavors have met a similar fate.

The Belgian CEFA activity appears more viable, however. Those who join, under a fee structure which I will shortly discuss, have several options open to them in pursuing a solution to their particular problem. They can either use CEBELCOR staff to perform the studies, the cost scale depending on whether the work is undertaken by the director, a research worker, or a laboratory worker, or they can send one of their staff to work at the Brussel's facility, free of charge. Alternatively, one of the CEBELCOR staff will be posted to the company's laboratory, according to another and more expensive pricing arrangement.

It must be apparent from the above descriptions that financial remuneration is a vital aspect of the entire program. This is, according to Pourbaix, simply because the organization depends almost totally on such funds for survival. It is only in the last year that very limited support has been forthcoming from the Belgian government, and continuation is by no means assured. Thus, to support the staff and associated facilities, CEBELCOR members who join CEFA pay an additional negotiated entrance fee plus an annual minimum amount of about $3000. This latter amount can be and usually is used to offset discounted hourly fees charged by the research staff. Fees for research range

from about $55 per hour for the director to $23 for a university research worker. CEBELCOR members who do not subscribe to CEFA pay 20% more, while outside organizations who are members of neither group pay an additional 50% surcharge. For all subscribers the work will be done on a confidential or open basis, as required.

In line with trends at other universities and laboratories, the funded work has become progressively more applied in nature. Years ago much of CEBELCOR's efforts were concentrated on such fundamental studies as the development of electrode potential/pH equilibrium curves describing regions of corrosion, immunity, and passivity for various metal/aggressive solution couples. Such diagrams have been catalogued and now are available from CEBELCOR in an *Atlas of Chemical and Electrochemical Equilibria*. This publication has become an invaluable aid in predicting what compounds will form and their relative reactivity when a given metal is in contact with a specific aggressive environment.

Much of this early work was concerned with reactions on pure metals at room temperature. Extensions of these diagrams to the technologically important area of alloys and higher temperature is proceeding but slowly owing to a lack of adequate support. Instead, funding is more often found for programs such as developing techniques for measuring local atmospheric corrosion rates, assessing why certain detergents and soaps damage washing machine liners, and corrosion control for specific industrial applications. While important, Pourbaix and I agreed that such studies must be balanced with more fundamental ones hopefully capable of producing much more general predictive recommendations for reducing atmospheric, aqueous and stress-assisted corrosion. To achieve this requires more extensive work of the type illustrated by some of the following research topics, which I have taken from a list of expertise and goals of the organization:

1. Equilibrium diagrams. a) Potential/pH equilibrium diagrams at 25°C, b) Atlas of chemical and electrochemical equilibria, at high temperatures.
2. Electrochemical methods for corrosion testing and control. a) Electrochemical testing methods for metals in the presence of water, b) Electrochemical testing methods for pitting corrosion, crevice corrosion, and stress-corrosion cracking, c) Electrochemical methods for atmospheric corrosion testing.
3. Pitting corrosion, crevice corrosion, intergranular corrosion and stress-corrosion cracking of metals and alloys in the presence of solutions containing chlorides, applications to marine corrosion, desalination plants, and surgical implants.
4. Atmospheric corrosion of metals and alloys.
5. Weathering steels.
6. Corrosion in the building and transportation industries.

Topics (1)-(3) are of great fundamental interest, but considering the current climate for research support, it seems clear that those areas closest to industrial interest stand the best chances for long-term support. This is borne out by ongoing research programs which largely fall within the applications section of topics (3)-(6).

In a very real sense Marcel Pourbaix is CEBELCOR. Any long-term future will depend on the success of the organization in broadening its scientific and technological base, expanding its membership, and most importantly establishing continuity in leadership. The increasingly active role of Antoine Pourbaix, the director's son, in CEBELCOR, suggests that this has been recognized. (I.M. Bernstein)

MATHEMATICAL SCIENCES

NUMERICAL ANALYSIS AND SOFTWARE DEVELOPMENT AT NPL

The National Physical Laboratory in Teddington, about 20 miles south of London, was established by Parliament in 1900 to serve as the British national standards laboratory. It is now a branch of the Department of Industry with a mission similar to that of the US National Bureau of Standards.

The purpose of my visit to NPL was to discuss recent R&D activities in the areas of numerical analysis and

scientific computing. Ever since 1945, the Laboratory has had an active research program in computer science and technology; and, until 1966, NPL was concerned with the development of both hardware and applications software. Since then, however, its efforts have been directed primarily toward the more effective use of existing machines and the exploration of new applications for computers. Of NPL's seven scientific divisions, the Division of Computer Science (DCS) and the Division of Numerical Analysis and Computing (DNAC) are the two computer-related R&D groups.

Examples of the types of projects that are carried out by the DCS are: Computer networking, data base research, computer vision and voice recognition, automatic word processing systems (computer editing), programming languages, and structured programming techniques. The Superintendent of the DCS is Mr. D.W. Davies.

Mr. E.L. Albasiny is Superintendent of the DNAC group which carries out research, software development, and consultancy projects in numerical and mathematical analysis. Although Dr. James H. Wilkinson holds the unique position of Chief Scientific Officer appointed on Personal Merit at NPL, it is the DNAC group with which he is most closely associated. (For a description of Wilkinson's accomplishments and distinguished honors see this author's article in *ESN* 31-9:363.) The 25-member staff of the DNAC work principally in the fields of linear algebra, differential and integral equations, approximation and data fitting, optimization, and integer linear programming.

In addition to Wilkinson's own well-known contributions to the algebraic eigenvalue problem, backward error analysis applied to the solution of large systems of simultaneous linear equations, etc., the DNAC group at NPL has also made major contributions in the other areas of numerical analysis cited earlier. One such recent accomplishment is the newly published text by Dr. George T. Symm of NPL and M.A. Jaswon entitled *Integral Equation Methods in Potential Theory and Elastostatics* (Academic Press, 1977) in which the authors provide an excellent up-to-date account of practical computational methods for the solution of integral equations.

In the area of optimization techniques, Drs. Philip E. Gil and Walter Murray have done important theoretical and practical work in the development of algorithms for the solution of both constrained and unconstrained nonlinear optimization problems. The computer programs developed from this research form part of the NPL Algorithms Library described later. Under NPL sponsorship, Gil and Murray have just completed a three-day tutorial in London on "Software for Numerical Optimization," the purpose of which was to instruct engineers, scientists and economists in the use of currently available optimization programs.

Much of my visit to NPL was spent in technical discussions of the work on approximation and data fitting carried out by the group headed by Mr. Geoffrey Hayes. The work in this area is basically concerned with two types of problems. On the one hand, it is often desirable—for reasons of computational efficiency—to approximate known mathematical functions by linear or nonlinear combinations of simpler functions. The other, and more commonly occurring problem, is that of approximating empirically sampled data. Over the past several years, the NPL group has developed a fairly extensive collection of efficient and reliable numerical algorithms for solving the most frequently encountered approximation and fitting problems.

Of particular interest is the work of Hayes himself on the fitting of functions or empirical data that depend upon more than one independent variable. By using cubic splines in two independent variables (i.e., bicubic splines), he has developed algorithms and computer software to handle approximation and data smoothing problems for both "well-structured data" and randomly scattered data. By well-structured, one means that the data is known in some systematic pattern such as along lines on which one of the independent variables is held fixed. Data given along a set of constant coordinate lines of a Cartesian coordinate system is the simplest example.

In practice, however, empirical data is more often randomly distributed over the domain of the independent variables, and here the problem of fitting

and/or smoothing the data is both mathematically more difficult and less precisely defined. A good example of this situation occurs in oceanography when data is collected from various sampling stations that are geographically scattered. Although the variety of problems encountered in fitting bivariate and multivariate empirical data is too great to be solved by any general purpose computer program, Hayes and his colleagues have developed a series of codes which allow the user to explore the data interactively and to decide for himself when he has fit the data to within acceptable accuracy.

Dr. Maurice Cox, a close colleague of Hayes, has done a great deal of work on the theory and applications of piecewise polynomial splines in one and more independent variables. Virtually simultaneously with Professor Carl deBoor of the Univ. of Wisconsin, Cox developed a very efficient algorithm for the numerical evaluation of spline functions based upon a particularly simple type of spline termed "B-spline." The deBoor-Cox Algorithm represented a significant advance in both the theoretical understanding of splines and in the development of faster and more accurate computer programs based upon splines.

As British government funding for fundamental research has declined over the past several years, NPL has been forced to seek R&D funds from the private sector and, in some instances, from international sources. For the DNAC, this has meant a greater emphasis on applications software development and the marketing thereof, as well as an increased amount of consultancy with other Divisions of NPL and external clients.

Perhaps the most visible result of this shift in emphasis from basic research to applicable research and software development is the NPL Algorithms Library, which aims to provide a collection of algorithms for those numerical processes most commonly encountered in engineering and scientific computing. Many of the algorithms produced at NPL are subsequently made available through the library service offered by the Numerical Algorithms Group (NAG) at Oxford. (For information on the NAG Library, see this author's article in *ESN* 31-2:54.) Although the NAG Library, since it is contributed to by a host of researchers throughout the UK, covers a much wider range of numerical software than that offered by NPL, the algorithms in the NPL Library can be purchased individually rather than as a total package. Hence, computing centers requiring a very complete software library will probably find the NAG Library most efficient and economical, whereas centers that desire only to supplement their existing libraries with selected, high-quality algorithms would be well-advised to investigate the catalog of subroutines available from NPL. Readers wishing more information on the NPL Algorithms Library should contact Dr. J.R.A. Cooper, Computing Branch, National Physical Laboratory, Teddington, Middlesex TW11 OLW. Information about the NAG Library may be obtained by writing to Dr. Brian Ford, NAG Central Office, 13 Banbury Road, Oxford OX2 6NN. (William J. Gordon)

MISCELLANEOUS

YET ANOTHER EXAMPLE OF CHANGING TIMES

As readers of the popular scientific press are no doubt painfully aware, it has become increasingly fashionable to write about how financial exigencies and government demands for accountability have diverted the research goals and philosophies of universities and laboratories, the net result being a larger and larger commitment to short-term projects and problem solving at the expense of fundamental studies having less immediate payoff. I plan to almost resist the temptation of debating the wisdom of such shifts in emphasis, particularly how they will affect the quality of the scientific and technological base in the 1990s and beyond. Instead, I want to describe yet another example of such changing times and one that in general seems to be working quite well.

For many years the Atomic Energy Research Establishment at Harwell in Oxfordshire has deservedly had the reputation of being, among other things, one of the world's great centers of materials research. The main focus on extending and developing understanding

of the physics, engineering, and materials problems associated with the exploitation of nuclear energy, particularly for power generation, provided ample flexibility to permit large groups of fundamentally-oriented scientists to pursue long-term basic studies. Particularly through the 1950s and 1960s programs on bonding in metallic and non-metallic systems, computer modeling of defects, radiation damage in solids, the role of dislocations in plasticity and fracture, etc., happily ticked along beside large-scale engineering-structure studies, welding investigations, and the like. Harwell became a center where academics from all over the world congregated for meetings and to use its excellent facilities for research studies.

Alas, came the late 1960s, and while the bubble didn't quite burst, it certainly deflated along with bubbles of varying sizes and surface tensions at similar institutions around the world. Hard-hearted accountants demanded bottom-line results for programs, causing a number of scientists to flee in apparent terror to other and hopefully more secure ivory towers (it is claimed that a listing of such places would not seriously exhaust the available writing space on a matchbook cover). Dire predictions sounding the death knell for basic research were heard throughout the land. But perhaps not unexpectedly it didn't really happen. Places like Harwell sighed and shifted, readjusted, survived, and then continued to flourish. Guidelines were changed—of course the research mix was significantly affected, and certain research areas were eliminated with the concomitant and often permanent loss of quality researchers, but the general structure seems to be intact.

Although during my visit I had limited exposure to a small segment of the total research effort, I received enough input to see how the general structure was adjusted. Very simply, Harwell became more immediately useful to its customers, who in the main are the government and the power generation industry. A significant fraction of the total research effort was now alloted to solving quite mundane problems, some to the point of fire-fighting. Also, and perhaps most importantly, Harwell aggressively began to sell its expertise. Outside contracts were so vigorously sought that now something like half of their 40-million pound annual budget no longer comes from its direct government allocation. Although it is hard for an outsider to judge, this mix seems to be reasonably successful. Harwell's relatively secure position, cemented by the important work it is doing on the reliability of nuclear and conventional power plants, has allowed quite a significant amount of fundamental long-term work to continue, particularly in the nuclear and solid-state physics area. It certainly appears prepared to mount a larger program in these areas if the pendulum swings or a new Sputnik flies, and basic research becomes again a cherished member of the scientific family.

Many of the research personnel with whom I spoke pointed out that quite interesting and quite basic studies could be done on mundane materials, such as steel and on dirty processes, such as welding, so that life in the laboratory could still be fun. Although I don't consider this either a surprise or a revelation, I have heard similar sentiments at enough different places to believe that such statements are not simply platitudes.

One of the more interesting changes at Harwell has been in the area of analytical services. They have always had an impressive array of state-of-the-art instruments, as many goggle-eyed academics will attest. These were available to users within Harwell and the rest of the atomic energy establishment and sometimes reluctantly to others. When the profit-center philosophy appeared, the situation dramatically changed. As one industrial consulting laboratory put it, seemingly overnight Harwell went from one of their biggest customers to their biggest competition. Glossy brochures rolled off the presses proclaiming the services available to paying customers.

To obtain more information on such activities, I visited Mr. B.W. Mott, group leader of the Solid State Instruments Group, a subgroup of a larger Analytical Services Division. All groups in the Division provide instrument time, operator, and interpretation depending on the needs of their clients. Somewhat surprisingly the rates charged are similar for all instruments, independent of sophistication and capital cost, and run around £200 a day. This

uniform costing is an accounting decision which Mott claims works quite well. The group is self-supporting, even including capital depreciation, permitting quite rapid updating of the instrumental capabilities at Harwell. This is, of course, the carrot, and since the researchers with whom I spoke did not complain about access time, the system seems to be successful.

Some of the physical methods of analysis available from the Solid State Instruments Group are:
(1) Scanning electron microscopy with a resolution down to 100 Å. One of the instruments incorporates an electron energy analyzer for Auger analysis of areas down to about 0.1 μm diameter.
(2) Electron microprobe analysis of areas down to 0.1 μm using both x-ray spectrometers and energy-dispersive analyzers. Two instruments are fully automated, and one of these may be used for the detection and analysis of the light elements carbon, oxygen, nitrogen and boron.
(3) Secondary ion analysis using a direct imaging mass analyzer. This technique employs a primary ion beam to give secondary ion emission for the qualitative identification of elements present at the surface. The rate of removal of surface atoms by erosion can be varied from one atomic layer per hour to about 100 Å per second. All elements of mass number down to hydrogen can be detected, and the detection limits are claimed to be as low as one part in a billion depending on the element, the rate of erosion, and the area of surface bombarded.
(4) Surface analysis by Auger electron spectroscopy (AES), x-ray photoelectron spectroscopy (XPS), and secondary ion mass spectrometry (SIMS). One spectrometer incorporates all the three techniques as well as ion-bombardment facilities for the controlled removal of successive atomic layers. Auxiliary equipment includes *in-situ* fracturing of specimens either under impact or tensile conditions for investigating such problems as grain boundary embrittlement, and side chambers for controlled surface attack for studying corrosion mechanisms.
(5) X-ray diffraction using a comprehensive range of facilities including a high-precision goniometer system. The diffractometers can be operated at temperatures ranging from 4 K to 2500°C, and are used for identification of compounds, measurements of lattice parameter, and crystal imperfections, and for the rapid determination of textures and the production of pole figures.

In additon to the services of this Division there are others; for example, the Industrial Research Group, the Materials Development Divison, and the Harwell Corrosion Service. These provide a host of services and products many of which are described in brochures and a monthly bulletin, the "Harwell Material Development News."
(I.M. Bernstein)

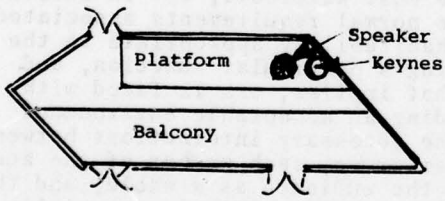
ACOUSTICS, THE THEATER, THE PERFORMER, AND THE AUDIENCE

Theater acoustics is a field requiring a careful blending of scientific knowledge with empiricism built on centuries of experience. It remains one of frustratingly unexpected technical surprise particularly in situations where the building involves a radically new design. Results achieved all too often appear to belie the application of accepted postulates and guidelines based on presumably firm scientific derivation. Of all the topics embraced within the field of architectural or building acoustics, theater acoustics is the most difficult, for in addition to the normal requirements associated with habitability appropriate to the building's particular function, and all that implies, one is faced with providing an acceptable environment for the necessary interactions between the performer, each member of the audience, the audience as a whole, and the building itself. This is especially true for the dramatic arts. Unfortunately, all too frequently halls or theaters are required to be multipurpose, calling for compromise between design principles that are frequently contradictory for different uses. Most difficult perhaps, the results are immediately available for all to see and hear. Fair enough, as good aural reception is usually considered to ride with good visibility for the audience.

A recent meeting at King's College, Cambridge offered the opportunity for continuation of the discussion of theater acoustics which has probably gone on for 2500 years or more. Apparently to the surprise of the organizers, but reflecting the widespread interest in this subject, substantially more than 100 attended the meeting on 14 February organized by the Building Group of the Institute of Acoustics. Although not finally sponsored jointly by the Society of Theatre Consultants as originally intended, there was substantial representation from the theater in addition to that from the architectural and acoustic communities. The latter grouping included numerous representatives from industry, the consultants, and universities, while the attendance as a whole was rounded out by a number of employees of local government. All attendees were from the UK, and this was very much a meeting on the British theater.

The combination of an unexpectedly large group and the nature of the Keynes Room in which the meeting was held demonstrated that even small "theaters" may have acoustic problems. Substantially wider than it is long, the Keynes Room is as high as long. A raised platform or stage along a longer wall is almost overshadowed by a balcony running along the opposite back wall. Adding

KEYNES ROOM



to the atmosphere, a massive bust of Keynes on a concrete base overlooks the platform from one side, and dominated the speakers. Finally, closely packed movable chairs on the lower floor contributed to the noise background while offering little comfort. All in all, the Keynes Room, although undoubtedly excellently designed economically to take advantage of a small space at the corner of King's College proved a difficult venue for this meeting.

Fortunately, as is common at meetings, but perhaps more so here, some of the speakers were excellent, well-prepared, with superlative visual aids and delivery. Further, it was clear that a number recognizing the situation took special care with their diction. Others—well, one can only say that they were at the other end of the spectrum with various combinations of the presenter being difficult to hear and using unintelligible highly complex or very low-contrast visual aids. It was a surprise to find such a range, at least one end of it, among a group discussing the theater.

Thanks to the organizers, however, attendees had a complete collection of extended summaries of the papers available at the meeting (but one couldn't read these when the lights were extinguished in an attempt to increase the contrast of the visual aids!). Albeit in difficult circumstances the organizers and some speakers did an exceptional job, proving the point brought out repeatedly during the meeting that in the final analysis its the performer's performance that counts. Nothing can replace or substitute for the good performer. Indeed, one felt an undercurrent that nothing should! Certainly at this particular show the poor performers enhanced appreciation of the good ones and demonstrated that the theater is not a building but a personal experience based on interaction between the player and the attendee, and that the building must not only allow this but enhance it.

Although not formally so divided, the meeting was in two principal parts. First, a general review and discussion of technical topics and second, an examination as case studies of five fairly recently completed UK theaters of widely different form.

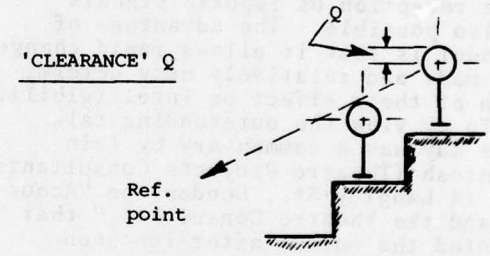
Opening the meeting W.A. Allen (Bikerdale/Allen/Bramble, Welwyn Gdn. City, Herts.) identified some possible issues; reverberation time, the noise level of ventilating fans, and the factors determining the intelligibility and character of the player's voice, and permitting reduction of his fatigue. R. Cowell (Sound Res. Labs. Ltd.,

Sudbury, Suffolk) followed with a general discussion of some of the main factors influencing good aural conditions in theaters, particularly for speech reception.

Discussing the importance of noise and vibration of both external and internal origin, Cowell noted the relatively high mechanical service noise of some UK theaters. Recognizing that while low-frequency noise is expensive to control and that its masking of speech is limited, he noted nevertheless that its character can be a distraction, and intermittent noises particularly so. He stressed the increased importance of audience and internal noises when noise levels are low. Turning to the distribution of sound within the theater to achieve intelligibilty and enhance voice quality, he stressed the need for direct and early sound and for intermediate midfrequency reverberation times (RT). Short RT's give good intelligibility but can affect speech quality and provide hard work for the performer. When the performer has his back to the audience, the direct sound level falls and early reflections must be provided to increase the early sound. The amount of this loss was discussed by a number of subsequent speakers with some disagreement in terms of back-to-front ratio. Apart from the acoustic aspects Cowell stressed the importance of comfort and visibility for listening. Turning to the use of sound systems, he noted live theater as one of the last areas to be invaded by the microphone, and suggested that speech reinforcement could be an aid particularly in larger theaters although much depends on this being well and discreetly done. Concerning the performer, Cowell noted the importance not only of audience reaction but of direct acoustic feedback to the performer either by reflection from surfaces or as reverberation. Concluding he stressed the need for developing better ways of advising design teams.

Two papers followed on aspects of human speech. N.T. Bowman (School of Architecture, Leicester Polytechnic) after enumerating the factors affecting speech intelligibility, proceeded to discuss various predictive models, including the speech map and the articulation index (A), and briefly outlined the effects of reverberation. He noted the importance of A and indicated how it can be computed. H.G. Latham (Heriot-Watt University, Edinburgh) expanded on the prediction of speech intelligibility during design, noted difficulties in the correlation between speech intelligibility and RT, and presented the outline of a prediction method employing a correlation analysis of subjective and objective measurements made in a number of existing auditoria (see Latham, "The Design of Auditoria for the Optimisation of Speech Intelligibility," *Acoustic Letters* 1 68, 1977). This technique is claimed as an improvement over earlier work which it extends (Lochner and Burger, "The Intelligibility of Speech under Reverberent Conditions" *Acoustic* 11, 195-200, 1961).

G. Andreas (Martin Centre for Architectural and Urban Studies, Cambridge) discussed what at first sight is a very simple problem, clear vision from every seat in the house with a minimum rake (or slope). Formulae for designing the rake contain assumptions about the stage and the observer, and often suggest solutions conflicting with other design requirements and compromises have to be made. A critical factor is "the clearance," Q. It entails considerable attention to the model of



the audience member—Is he uniform? Does he move? Is he, he or she? Are seats staggered or to what extent can they be staggered? Andreas noted that Q has been decreasing with time from Russel's 305-457 mm in 1841 to Ham's 100 mm in 1972. He presented values of Q based on a bimodal distribution of anthropometric data for seated males and females and concluded that a Q of 150-200 mm would yield a high probability of clear vision. A critical discussion of the theater rake problem by Andreas is available in *Transactions of the Martin Centre* Vol. 2, 1977.

Dr. M. Barron (Univ. of Cambridge) the local organizer of the Meeting, concluded the general review of technical topics with a discussion of current research on theater acoustics at the Dept. of Architecture, Cambridge. He noted the immense amount of effort that has and is being devoted to speech but regretted that little of this was specifically aimed at the theater. Particular attention has been paid at Cambridge to the directional characteristics of speakers, a topic of growing concern with the use of thrust and open stages. Objective directional data is available and has been confirmed, but subjective measurements are required to clarify the effects on speech reception. Considerable effort is being devoted to model work. A 1/8-scale model is used, with 8 times normal acoustic frequencies, in which air absorption is scaled by using air of 2% relative humidity. A source has been built using a tweeter loudspeaker and inverted horn emitting from a 6-mm aperature to simulate a speaker. This can be employed for subjective tests using speeded-up speech as the input signal, and slowed down microphone output recordings. Companion objective studies of the reception of impulse signals are also possible. The advantage of the model is that it allows rapid changes to be made and relatively easy determination of their effect on intelligibility.

To my view the outstanding talk of the day was a commentary by Iain Mackintosh (Theatre Projects Consultants Ltd., 14 Langley St., London) on "Acoustics and the Theatre Consultant," that prevented the normal after-luncheon let down. Claiming no expertise in acoustics and stressing his classical education, he put the subject in perspective, ably using his own store of case studies to demonstrate the current status and problems. His examples included the Stratford Memorial Theatre with its extensive series of modifications from a 1000 seater in 1932 to the present 1536—which works, the design of an excellent existing opera house that could not work, and experiences with a very noisy ventilating system, apparently acceptable to many who lived with such environments! Discussing the roles of the acoustician and the theater consultant at different stages in a design, he identified three important coming changes affecting design. First, introduction of efficient remotely controlled luminaires helping the design problem; second, electroacoustics and third, the trend to the galleried courtyard form which will affect rules established for single-rake theaters. Clearly not an advocate of the microphone, at least for the theater, or of the very large auditoria which need it when used as a vehicle for live theater, he ably presented some of the disadvantages; (a) homogenized sound—clean sound from hi-fi actors lacking variation or dimension, (b) another technical device which the performer must master, and (c) impact on the performer-audience interactions which would change theater as a whole. In support of his views, he tends to equate the microphone with binoculars, he quoted from an early 19th century critic at the time when Drury Lane and Covent Garden trebled in size—"On the stage of Old Drury in the days of Garrick, the moving brow and penetrating eye of the marvellous actor came home to the spectator. As the passions shifted and were in turn reflected from the mirror of his expressive countenance, nothing was lost; upon the scale of Modern Drury many of the finest touches of his act would necessarily fall short. The distant audience might chance to catch the text, but would not see the comment."

In conclusion Mackintosh called for closer cooperation and consultation between the various experts even of a given field, advocating in this regard a review of existing UK theaters, listing characteristics and summarizing opinion—*à la* Beranek in his *Music, Acoustics, and Architecture*.

I will do little more than list the theater case studies presented in the course of the Meeting, referring the interested reader to the published Proceedings for additional information (see below).

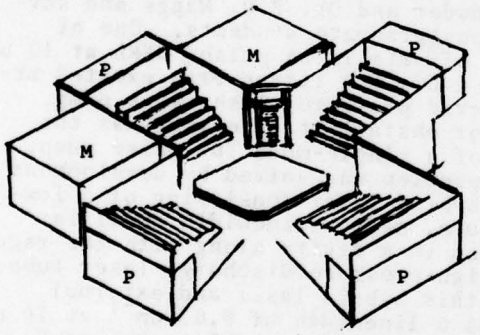
The Eden Court Theatre, Inverness, is by all accounts a most successful small theater (800 seats) designed to meet a variety of requirements, including drama, opera, ballet, orchestral music, conferences, popular concerts and social events. It has a tiered horseshoe form with raked stalls, and is described as "papered with people."

The main theater of the Crucible, Sheffield, has a thrust stage and seats 1000 on a steep rake with no one more than 60 ft from stage center. Reverberation times at 250 Hz and above are perhaps too short.

The Royal Exchange Theatre, Manchester, is carried on steel trusses from the marble columns inside the Exchange building. Its structure is largely steel and glass, the latter to meet safety requirements for audience visibility of a fire in the surrounding Exchange. The design accommodates up to 750 for "theater in the round" using steep raking. The upper panels of the walls can be opened as louvres, increasing the feedback from the outer building and this is exploited for music.

The Alfred Beck Centre Auditorium, Hillingdon, Middx., was designed for a wide range of uses from cinema and speech to symphonic and choral music. The bulk of the seating is on a single rake, with 3 additional rows of seats which may be lifted from the pit. It accommodates 598. An assisted resonance system is available. This is fortunate as there are difficulties with RT which has proved substantially shorter than designed. The speaker noted a critic's comment after a chamber orchestra concert to the effect that "Sound is successfully defused (*sic*) rather than localised" adding that "One has to be thankful for every kind word, even for a misspelt one." But was it?

The theater of the Grange Arts Centre, Oldham, has a Greek cross plan with a central stage and music rooms,



P-Plant M-Music Rooms

GRANGE ARTS CENTRE

etc., in the corner spaces. Seating for 400 is on movable bleachers in the arms of the cross. Provision is made for different stage and seating configurations. There are difficulties with acoustic insulation and with noise from the bleachers, and possibly too much attention was given in the design to speech rather than music.

Quite a collection, and if representative of the 200 UK theaters and auditoria designed and built in recent years, indicative of the complex nature of the current theater acoustic problem. One can appreciate a call for a return to established proven designs!

All in all this was an excellent Meeting; the Meeting's environment probably aiding an appreciation of the subject. The centuries-old discussion of theater acoustics was enthusiastically continued. Whether any firm conclusions were reached or could be reached is another matter. A questioning of the nature and timing of the interaction of the various disciplinary inputs to the design team was repeatedly called for as was clarification of acoustic design guidelines. A critical review of existing theaters and of their characteristics and problems, advocated by a number of those present, *should be a very good* starting point.

A Proceedings of the Meeting is expected to be available from the Institute of Acoustics, 47 Belgrave Square, London SW1 8QX at a cost of about £2. ($4.00). (A.W. Pryce)

PHYSICAL SCIENCES

LASER SPECTROSCOPY AT EDINBURGH

The Physics Department of Heriot-Watt University is located on the Riccarton campus site in the suburbs of Edinburgh. The laboratories and facilities are relatively new having been built up in the period 1970 - 1974. Professor S.D. Smith (presently on sabbatical leave at the Projectgruppe für Laserforschung der Max-Planck Gesellschaft at Garching, FRG) came to head this department in 1970 from Reading University and brought a project on ir sounding from satellites with him along with several people. The group now consists of 23 faculty, 15-20 PhD students and 10-15 postdoctoral assistants.

The primary emphasis of work in the Department is in the area of laser spectroscopy. The most important contribution by Smith's group in this field has been the development of cw and pulsed spin-flip Raman lasers (SFRL) which produce tunable ir radiation. These lasers are based on stimulated Raman scattering from conduction electrons in InSb in the presence of a magnetic field. Other laser spectroscopy work is being conducted through development of tunable dye lasers and optoacoustical detection techniques. Infrared optically-pumped lasers are also being developed. These lasers are pumped with CO_2 or other ir lasers and population inversion produced on vibrational or rotational transitions in absorbing gases. Additionally work on mesh interference filters for the ir spectral region 60 - 1000 μm is being pursued. There are a few other efforts being carried on in the Physics Department; however, the laser work is the most significant and will be the main topic of discussion in this report.

The InSb tunable SFRL operates in the spectral range 5 - 6 μm and holds much promise for spectroscopic studies of molecules. Smith, Dr. R.B. Dennis, Dr. C.R. Pidgeon, and several graduate students and other assistants have been working in this area since 1970. In the last few years the group has been concentrating on achieving the characteristics of ultra-narrow linewidth, stable amplitude, and linear tuning capability.

The cw SFRL is pumped with a CO laser which has several lines (5 - 6-μm wavelength) within the band gap of InSb. The InSb crystal is cut with parallel ends thus forming a Fabry-Perot laser cavity. The crystal is then lowered in temperature to 4 K and then placed in a variable magnetic field which tunes the Raman scattered radiation. However, there is a competition between the variable-frequency Raman gain and the fixed Fabry-Perot mode frequencies that depends only on the optical thickness of the cavity. The output shows modulation, discontinuities, and nonlinear tuning rate through a mode as the magnetic field is varied.

Two techniques have been used to reduce these effects. The first utilizes antireflection coatings on the end faces of the crystal. This reduces the cavity "Q" resulting in a broader cavity mode width that has the effect of reducing the modulation and tuning nonlinearity. The second method utilizes a long external cavity in conjunction with the antireflection coatings. The external cavity is now dominant over the cavity formed by the crystal so that the cavity-mode frequencies are determined by the latter cavity. One of the mirrors of the external cavity is mounted on a piezoelectric transducer that is connected to a lock-in amplifier, and a feedback signal applied to the transducer which changes the cavity length so as to maintain maximum output as the laser is tuned by the magnetic field. It is expected that these new techniques will permit the SFRL to be used as an ir spectrometer with good linearity and with a resolution of 100 kHz over a 10-cm^{-1} spectral range.

Additional work related to cw SFRL is being carried out on single frequency operation of the CO pump laser and fundamental optical processes in InSb including four- photon mixing and stimulated Stokes radiation to produce other tunable outputs. A second aim is to obtain cw SFRL operation at 10 μm.

Another program on pulsed-laser spectroscopy is being actively pursued at Heriot-Watt with an impressive group of 10 people including Pidgeon, Dr. R.G. Harrison, Dr. R.L. Alwood, Dr. G. Crowder and Dr. P.D. Maggs and several postgraduate students. One of these efforts is on pulsed SFRL at 10 μm using a CO_2 TEA (transverse excited atmospheric pressure) laser as a pump. A major obstacle to the work was the lack of a single-mode TEA laser pump. This problem was solved by development of a hybrid laser consisting of a low-pressure, narrow-linewidth amplifier section in a cavity along with the regular high-pressure discharge laser tube. With this hybrid laser and external optics a linewidth of 0.03 cm^{-1} at 10 μm is obtained. The tunable range is 9 - 13 μm or 5.3 - 6.6 μm (two photon resonance) when pumped with a pulsed CO_2 laser.

The cw and pulsed SFRL sources described above leave large gaps in the ir spectrum. Smith's group is attempting to fill these by developing new pump lasers for the SFRL and also other new laser sources. Two programs are underway. One investigation concerns the far infrared (FIR) and the

other the near infrared. The FIR work is based on the use of small-waveguide laser cavities containing various gases at pressures of about 10^{-4} atm pumped by a quasi-tunable CO_2 laser. Far-infrared emission has been obtained from several gases including methanol at wavelengths of 118, 193, 570, and 70.6 μm and from methyl fluoride at 496 μm. Laser action in these systems is brought about by inversion of specific rotational levels as a result of absorption by levels coincident with those of the pump laser. The group has recently made significant advances in near-ir sources in the 1 - 30 μm range through optical pumping of vibrational levels of various molecules. An important example of this is the production of 12.8-μm laser emission from NH_3 after excitation by a 9-MW, CO_2 pulsed TEA laser operating at 9.29 μm. This work was described recently in the literature [F.A. Al-Watban, R.G. Harrison, J.G. Crowder, and C.R. Pidgeon, *J. Phys. D: Appl. Phys* 10, L167 - L170(1977)]. A 70-cm length of NH_3 was contained in a 12-mm square cross-section brass tube. The latter served to deflect the pump radiation into the NH_3 laser mode volume to provide efficient pumping. A maximum output power of 775 kW was obtained at a pressure of 9 to 10 Torr.

Another project in laser spectroscopy in the Department differs considerably from the work just described. Dr. M.J. Colles is doing what he refers to as "triple spectroscopy." He simultaneously conducts absorption, fluorescence, and opto-acoustic measurements on gaseous samples using a tunable dye laser as excitation source. Colles and E. Marinero have recently studied I_2 with this technique. It was found that the energy absorbed by the vapor was not equal to the thermal energy detected in the opto-acoustic measurement plus the fluorescent radiation. Colles and Marinero interpreted this result as arising from spontaneous predissociation of iodine in the $^3\pi_{ou}$ state (B state) due to level crossing of this state with the $^1\pi_u$ state. The latter state is repulsive, hence coupling to this state results in predissociation. Changes in fluorescent yield were observed for different vibrational levels of the B state, thus the cross over position of the B state and repulsive state can be estimated. However, it was found that measurement of fluorescence alone was insufficient to determine the complete picture as radiationless decay also reduces fluorescence yield. Opto-acoustic measurements provide direct information on the radiationless decay path. The total energy put into the system is determined by absorption measurements. Colles feels that measurement of all three spectra permits the determination of the extent of predissociation for particular vibronic levels, the position of level cross over and variations in quantum yield.

Dr. G.D. Holah and others in the Department are working on FIR mesh interference filters for NASA. This is an offshoot of a satellite program started earlier by Smith at Reading University. Holah believes he and his colleagues are far ahead of others working in this difficult field. They have successfully produced narrow-bandpass filters having 60% transmission for $\lambda \geq 50$ μm with half widths less than 5% without using spacers. They have also produced lowpass filters and now are attempting to produce broad-bandpass filters. Dr. G. Peckham is also pursuing satellite work which is a continuation of his earlier work at Reading. He is concerned with passive ir-temperature sounding and surface pressure measurements based on active microwave measurements on an O_2 line at a wavelength of 5 mm.

This is a large and productive group with high quality researchers and excellent leadership. The group has also been instrumental in establishing a small company, Edinburgh Instruments Ltd., which is located in close proximity to the University. The company has developed commercial products such as dye, CO_2 and CO lasers, opto-acoustic detectors, monochromators, and electronic instruments. They work in close coordination with people from Smith's Department and others in the University. (Vern N. Smiley)

FLUID MECHANICS AT THE UNIVERSIDAD POLITECNICA DE MADRID

At the Universidad Politécnica de Madrid in the Escuela Tecnica Superior de Ingenieros Aeronauticos (ETSIA), there is an up-to-date program in Fluid Mechanics. The director of ETSIA is Prof. F. Garcia Moreno, and the Chair in Fluid Mechanics is held by Prof. Amable Liñan. A related Chair in Aerodynamics at ETSIA is held by Prof. Ignácio Da Riva. The Fluid Mechanics program at ETSIA is closely associated with the research activities of Drs. Carlo S. Tarifa and Antonio Crespo of the Instituto Nacional de Teĉnica Aerospacial "Esteban Terradas" (INTA) in Madrid.

The research activities in Fluid Mechanics are concerned in good part with combustion, and in this regard, a number of interesting interface problems have been and are under investigation. In the area of fuel droplet evaporation and combustion, Crespo and Liñan have jointly studied the nonsteady burning of droplets in terms of an asymptotic theory which is a perturbation about the usual quasi-steady analysis. The quasi-steady theory holds for a liquid droplet which is of much greater density than its steady, gaseous environment. However, the conditions inside liquid-propellant rocket motors and diesel engines are such that nonsteady effects are important. The analysis assumes that the droplets are at their boiling temperature and that the flames are characterized as thin spherical shells concentric with the droplets. The Crespo-Liñan theory is consistent with previous numerical results and experiment.

Liñan and Crespo have also studied unsteady diffusion flames for large activation energies. The problem concerns the mixing and simultaneous chemical reaction of two reactants undergoing a single-step irreversible reaction. If the fuel and oxidizer reactants contact each other initially across an interface, a premixed region develops in which thermal runaway (ignition) occurs. A deflagration region in which the deficient reactant is consumed by flames propagating from the ignition point then develops. Finally, there is a region in which a thin diffusion flame exists where the reactants are present in stoichiometric proportions. The reactants must diffuse toward each other through layers of reaction products; the diffusion flame consumes those reactants not consumed in the premixed flame region. Not only have similar solutions been obtained for the flames between reactants initially at rest with respect to each other, but a treatment of the corresponding problem with velocity shear between the reactants is projected for the laminar flow case. It should be noted, however, that such a laminar shearing region is highly unstable and a turbulent mixing and burning region is a more realistic situation for study.

The problem of the ignition of a reactive solid by an inert (nonreactive) hot spot such as an electrically heated wire is also under study. In the case of a hot wire, a heat pulse propagates out from the wire in the form of a cylindrical surface. If the surface curvature is too high (the radius is too small), extinction of the reaction may occur due to the geometrical dilution of the heat flux. Therefore, in order for ignition to occur, there exists a minimum critical radius of the wire which is a function of the wire temperature.

A recent study of Liñan's when he was still at INTA concerned the production of nitric oxide in laminar and turbulent diffusion flames. The production takes place in the normally assumed "frozen" high-temperature region adjacent to the principal (fuel-oxidizer) reaction zone and is modeled as an approximation of the reaction mechanism first proposed by Prof. Ya. B. Zeldovich of the USSR Academy of Sciences. The turbulent case is modeled using a probability distribution function for the concentration of the chemical species as first introduced by W.R. Hawthorne, D.S. Weddell, and H.C. Hottel, and it is shown that the nitric oxide production is dependent on the detailed shape of this function. A method for calculating the probability distribution function has also been devised.

Dr. Javier Jimenez, who in addition to his activity at ETSIA also works for the IBM Company in Madrid, is investigating the mixing layer experimentally in Liñan's laboratory. The study is being carried out in a water tunnel of 15 cm × 15 cm cross section where the streams on each side of the mixing layer can be independently varied in velocity from 10 cm/sec to 70 cm/sec. Jiminez will obtain the angles of

spread and the dominant disturbance wave numbers for a range of velocities of both streams. The purpose of the investigation is to study the details of the roll up of the interface between the streams so that the turbulent combustion properties of such a flow configuration can be inferred.

Liñan is also cooperating with Prof. Juan R. Sanmartin, who holds a Chair in Physics at the Universidad Politécnica, and Dr. A. Barrero of the ETSIA in a theoretical study of the fluid mechanical aspects of laser fusion. In particular, they are obtaining the self-similar solution of the one-dimensional motion of an electron-ion fluid with different electron-ion temperatures as generated by a hypothetical laser pulse depositing energy in a plane surface. The integral solution compares to a numerical solution of the governing equations with remarkably good agreement. However, the solution is laminar, and in view of the instabilities which are certainly present, it would be well to estimate what the dominant disturbance wave number and turbulent compression wave thickness might be.

Da Riva at ETSIA is concerned with designing flow experiments for a space-laboratory. Such subjects as processing in space, growing crystals, and the study of spin-up along with attendant hydrodynamic instabilities are projected.

The equipment of the laboratory consists of a 1 m × 1 m cross section 75 m/sec straight-through wind tunnel which is being used for demonstration purposes and industrial testing of wind forces on buildings, a smoke tunnel (2 m × 10 cm) that is used to study the wakes behind windbreaks and for student demonstration, a demonstration water tunnel, and equipment providing a hydraulic analogy to compressible flow. Despite the difficulty in obtaining and maintaining support for the research program, along with the prevailing low academic salary scale, the Fluid Mechanics activity is one of quality. (Martin Lessen)

PSYCHOLOGICAL SCIENCES

IF HEBREW CAN BE TYPED WITHOUT MUCH TRAINING, CAN ENGLISH BE FAR BEHIND?

The digital computer is a remarkable device, but there is nothing remarkable about human input to it. Our information-processing institutions use computers with alphanumeric keyboards for manual data entry much like the office typewriter, and keyboard users will often painfully enter data with the hunt and peck system. Hundreds of hours of practice are required to achieve 60 words per minute, which is a typical speed for a good secretary, and thousands of hours of practice will push the typist toward the 150 words per minute that is championship speed. A stenotyping system (the court steno-writing system), which uses a "chord" keyboard where two or more keys are pressed simultaneously and the unit of encoding can be larger than the single letter, can yield 150-200 words per minute or more with long training. Most people, however, lack the will to reach these enviable levels of proficiency, and no one seems to mind very much. Management is tolerant of the personnel costs associated with slow data entry, and the information systems in which computers are commonly embedded (inventory, payroll, banking, research data) do not require speedy entry. There are, however, computer-using systems that benefit from rapid input. Computers are now commonplace in high-speed aircraft, and there are circumstances where fast data entry by the aircrew is necessary. Military command and control functions can use a digital computer for information storage and processing, and manually inserted data will come to it from many sources. That amateurish typing could degrade the performance of a commander in charge of thousands of men and billions of dollars in equipment speaks to a link in need of strengthening.

The standard English typewriter keyboard, called the QWERTY keyboard, is difficult and requires long training for proficiency, so there is little hope of easily training the world to use it well. If so, why not go the human engineering route and re-design the

keyboard so anyone can learn to type quickly? This possibility has not been ignored. A notable interest, which has now faded, was in the Dvorak keyboard that arranged the keys according to frequency of letter occurrence in the language, with the most commonly used letters on the home row. The problem with the Dvorak keyboard is retraining; typists have negative transfer from experience with the QWERTY keyboard, and extensive training is required to overcome it and acquire the new skill. One study by E.P. Strong (US General Services Administration, 1956) gave an experimental group 28-days retraining on the Dvorak keyboard, and performance was found to be about the same as a QWERTY control group. Strong found little justification for advocating the Dvorak keyboard. R. Seibel (Dept. of Psychology, Penn. State Univ., Univ. Park, PA) estimates that re-design of the QWERTY keyboard cannot expect to yield gains of more than 10%, and at the expense of extensive re-training. [See Seibel's chapter in *Human Engineering Guide to Equipment Design*, ed., H.P. Van Cott and R.G. Kinkade (US Government Printing Office, Washington, DC, 1972).]

Chord keyboards have held promise, but the experimental studies of them have not caused us to throw out the QWERTY keyboard. Consider a study by Seibel (*Human Factors* 6, 189-192, 1964) where a QWERTY keyboard was modified for chord response to parts of words, words, or phrases. With 75 abbreviations and 70 hours of practice, rates were 112-125% of QWERTY rates. With 150 abbreviations and more training still, rates were 150% of QWERTY rates. In effect, Seibel demonstrated what stenotyping demonstrates—that a chord keyboard can be better than a QWERTY keyboard. Like the QWERTY keyboard, a chord keyboard is costly in training.

The villians of the piece are training and negative transfer, and they would be eliminated if a keyboard could be conceived that requires very little training and does not suffer from prior experience with the QWERTY keyboard. Essentially such a claim was made by R.C. Sidorsky (US Army Res. Inst. for the Behavioral and Social Sciences, Alexandria, VA) for his new chord system called Alpha-Dot which has the single letter as the unit of coding (Tech. Paper 249, US Army, Res. Inst. for the Behavioral and Social Sciences, Jan. 1974). One-handed operation of three keys is all that is needed for the 36 alphanumeric characters. Each character is entered by two strokes, with each stroke consisting of one or more keys pressed down simultaneously; the coding is both parallel and serial. Another way to look at it is that a character is spread out in time, with part of its structure represented in the first stroke, and the rest of it in the second stroke. The letter *A*, for example, consists of pressing key No. 2 on the first stroke, and keys No. 1 and 3 on the second stroke. Notice that the key press sequence forms a triangle, resembling, crudely, the triangularity of the letter *A*. The coding that Alpha-Dot exploits is in the shape of the characters, and it is stored in memory for all of us as the imagery that we have for alphanumeric characters. That spatial imagery can benefit human performance is gaining a solid experimental base [for example, see the chapter by L.R. Peterson *et al*, *the Psychology of Learning and Motivation*, ed. G.H. Bower (Academic Press, New York, NY, 1977) Vol XI]. Sidorsky reported a pilot experiment in which his subjects, who were substandard typists, were given five hours of practice on Alpha-Dot. Performance on Alpha-Dot was compared with performance on the QWERTY keyboard, and Alpha-Dot performance was 60% of that on the QWERTY keyboard when conventional text was typed. These are not stirring results, so Sidorsky's study did not arouse the keyboard scene at the time.

The next chapter in this saga is set in Israel. D. Gopher (Israeli Air Force Aeromedical Center, Tel Hoshomen, and the Faculty of Industrial & Management Engineering, The Technion, Haifa) is an engineering psychologist who became intrigued with the potential of Alpha-Dot. He believed that the modest outcome of Sidorsky's study was a matter of the perceptual complexity of the characters of the Latin alphabet, and the difficulty of translating our imagery of the characters into double-stroke presses of three keys, not a weakness of the Alpha-Dot concept. Hebrew, he reasoned, is simple and "square" in form and can be easily imaged and externalized in presses of three keys. Gopher found that Alpha-Dot touch typing of Hebrew characters could be learned in 5-10 minutes, with some subjects getting

all letters correct on the first try. In one hour the subjects had the same speed that they had on the Hebrew version of the QWERTY keyboard. Experienced subjects did 120 letters/minute. Currently, Gopher is collecting more data on Alpha-Dot. Plans are active for its operational use. Pilots are enthusiastic about it because its one-hand touch operation is a minimal distraction from the central task of aircraft control.

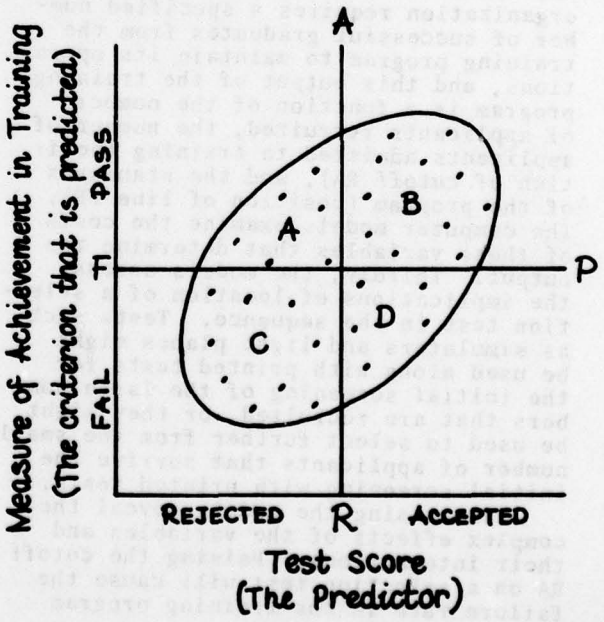
The time will come when voice recognition is part of our everyday technology (see *ESN* 31-11:466, for example), and we will be able to talk to machines with a standardized vocabulary. Voice can then be used for data entry rather than keyboards. A voice recognition machine will never beat the cost of a keyboard, however, so Alpha-Dot may find its place in the sun, at least in Israel. The ultimate achievement will be one masterful keyboard that can handle the imagery of all alphabets, from square Hebrew to the swirls of Arabic, with minimal training. (Jack A. Adams)

COMPUTER MODELS FOR PERSONNEL SELECTION

Both the military and industry face the continuing problem of personnel selection. A pool of applicants is available for a job, and a test battery is commonly used to select those that are best qualified. Most often, the tests are printed paper-and-pencil instruments, which are low cost and easy to administer, but in principle they can be any device or situation that yields a performance measure. The essential requirements for a test in the battery are that the score be reliable, or stable on different test occasions, and valid, or correlate with success on the job. For a long time in psychology, reliability and validity were the only operations that were performed on a test to establish its usefulness, but today personnel psychologists are aware of a more complex picture. Testing can produce a number of difficult management decisions that relate to costs and adequate numbers of personnel for the system, so the power of tests to select personnel reliably is only one consideration (although obviously an important one).

These problems were highlighted for RAF personnel psychologists when they found that, for the world of personnel selection, both a 4-hour training program in a flight simulator and a 14-hour training course in a light plane were highly successful in producing performance measures that predict achievement of RAF pilot trainees in their flight training program. The correlation between performance in the flight simulator and success in flying school was 0.76, and the correlation for the light plane was a phenomenal 0.91 (a perfect positive correlation is 1.0). The test battery that is regularly used has a validity of less than 0.40, so validities of 0.76 and 0.91 were cause for excitement, but restrained excitement because the cost and complexity of simulators and aircraft place them in a different league from printed tests. L.V. Bennett and A.D.W. Partridge [Ministry of Defence, Science 3 (RAF), Whitehall, London],and I.G. Lidderdale (RAF Headquarters Training Command, RAF Upwood, Cambridgeshire) faced the problem by building two computer models, called RESET, to weigh the factors and provide the substance for decision.

The model domain is illustrated by this figure showing the relationship between a selection test that is the predictor and a criterion that is being predicted:



The ellipse surrounds a hypothetical plot of a score pair for each individual of a sample of applicants (the dots in the drawing)—a score on a selection test and a score for success in a training program. The measure of achievement is pass/fail in the training program, with those falling above the line FP passing and those below failing. If the students were unselected, the proportion of passes would be (A + B)/(A + B + C + D). When a selection test is used, only those to the right of the cutoff line RA are admitted to training, with the proportion of passes now being defined by B/(B + D), which is the output of the training program.

The ratio B/(B + D) can be influenced in three ways:

1. The validity of the test. The more valid the test the more compressed the ellipse.
2. The cutoff (vertical line RA) assigned to the distribution of test scores. The number of trainees admitted to training is controlled by moving the line RA to the left or the right.
3. The standards for judging performance in the training program, represented by moving the line FP up or down.

The RESET models basically do three things: First, they examine the implications of tests with different costs and validities. Secondly, the using organization requires a specified number of successful graduates from the training program to maintain its operations, and this output of the training program is a function of the number of applicants recruited, the number of applicants admitted to training (position of cutoff RA), and the standards of the program (position of line FP). The computer models examine the costs of these variables that determine the output. Thirdly, the models assess the implications of location of a selection test in the sequence. Tests such as simulators and light planes might be used along with printed tests for the initial screening of the large numbers that are recruited, or they might be used to select further from the smaller number of applicants that survive the initial screening with printed tests.

Exercising the models reveal the complex effects of the variables and their interactions. Raising the cutoff RA on a selection test will cause the failure rate in the training program to decrease, but because fewer trainees are being selected the output of the training program will be reduced. To maintain a sufficient output, the number of applicants tested and screened must be increased. A good selection test like a simulator or a light plane will decrease the failure rate in the training program, which is economical, but higher recruiting and testing costs that result from their use oppose the savings. Both of these opposing factors are a function of the level of the cutoff RA, and analysis showed that an intermediate position for RA produces the required output of personnel while minimizing costs.

Other cost analyses were directed at the optimum point in the selection and training sequence at which an expensive selection test, such as a simulator or a light plane, should be used. It is costly to make such an expensive test part of the printed test battery and administer it to the large pool of applicants that are tested at the outset. And it is costly to administer it near the end of the training program because much money has been spent on those who are rejected and who must be replaced if the output is to be guaranteed. The most cost effective approach is first to screen the large applicant pool with inexpensive printed tests, and then apply the expensive test at an intermediate point in the sequence to further select among the smaller number that remain.

Actual cost figures from RAF accountants were used in the models. The recommendations that are derived from the models and made to RAF management are in terms of realistic functions expressed in actual money rather than idealized functions that lack explicit ties to the real world. (Jack A. Adams)

ONRL REPORTS

See the back of this issue for the abstracts of current reports.

EVIDENCE FOR A NEW BIOLOGICAL RHYTHM IS EMERGING

Biological rhythms, as periodicities that affect biological and behavioral responding, have interested scientists for some time. Prominent among these periodicities are the circadian (24-hour) rhythm and the menstrual cycle. The evidence relating these cycles to biological and behavioral functions can be mixed, but it is positive enough to convince investigators of their reality (See W.P. Colquhoun, Editor, *Biological Rhythms and Human Performance*, Academic Press, 1971). Dr. Peretz Lavie, (Dept. of Behavioral Biology, Aba Khoushy School of Medicine, Technion, Haifa, Israel) is the force behind a series of experimental studies whose findings converge on a new rhythm of about 90 minutes, which he calls the ultradian rhythm.

N. Kleitman (Univ. of Chicago, retired) suggested the 90-minute cycle several years ago (see Kleitman's chapter in A. Kale's book, *Sleep Physiology and Pathology: A Symposium*, Lippincott, 1969). Rapid eye movements (REM) during sleep have gained status as a scientific topic because they are a reliable index of dreaming, and Kleitman was the pioneer investigator of it. Kleitman, in his well-known book, *Sleep and Wakefulness* (revised edition, Univ. of Chicago Press, 1963), reported that REM-nonREM sleep has a cycle of about 100 minutes, which Kleitman found consistent with reports in the literature of regular and irregular respiratory movements during sleep having a periodicity of about 100 minutes, an EEG periodicity during sleep of about 90 minutes, and penile erections in the sleeping male having an 85-minute cycle. Kleitman suggested that these sleep phenomena were part of a more encompassing biorhythm that continues around the clock whether we are asleep or not, and he called it the "basic rest-activity cycle"; it has also been called the "biological hour."

Not much was done with Kleitman's hypothesis until Lavie picked up on it, using the REM-nonREM periodicity as his point of departure. If REM and nonREM sleep are part of a fundamental rhythm, then it should determine more than dreams, and so his initial approach was to awaken subjects during REM and nonREM sleep and administer perceptual tests to them. One of the tests was the spiral aftereffect. Fixate a rapidly rotating Archimedes spiral for, say, 30 seconds. When the spinning is stopped, the subject will have the illusion that the movement is continuing for some seconds, and the duration of the illusion is timed. Lavie found longer durations after REM sleep than after nonREM sleep. The other perceptual test was Beta movement, or apparent motion. Alternately flash off and on two lights a small distance apart with flashing frequency as the variable. At high frequencies the subject will see the two lights as being on simultaneously. As the frequency is lowered the subject has the illusion of one stimulus moving across the field, and when the frequency is lowered still further, the subject sees two lights being on in succession. Lavie found that his subjects saw movement over a greater range of frequencies after REM sleep than after nonREM sleep. After establishing that these two perceptual responses are correlates of the REM-nonREM cycle, Lavie went on to show that they have a 90-100 minute cycle during waking hours as well, and that the two responses cycle in phase. As Kleitman hypothesized, the REM-nonREM rhythm would seem to be part of a basic rhythmic pattern overlaying the full 24 hours.

Lavie has turned toward physiology in his most recent work. Urine samples were collected from his subjects every 10 minutes for 10 hours. The measures were amount of urine, Na^+ and K^+ concentrations, and urinary osmolality. All variables had one cycle per 80-133 minutes, but urine output was out of phase with the other 3 measures, which were in phase with each other. Another study recorded stomach contractions and eye movements throughout a night's sleep. Gastric contraction cycles and REM-nonREM cycles were both about 100 minutes but, as with the other study, the physiological measure was out of phase with the behavioral measure. Why behavioral and physiological measures maintain the same frequency but lack phase relationship, and what this means for Kleitman's hypothesis, is not clear.

Granting a 90-minute cycle, how is it explained? Rhythm theorists think along 2 lines. One line says that a rhythm is sustained internally without dependence on an environmental periodicity. The menstrual cycle is an example. The other line says that rhythm is a response to periodicity in the

environment. The diurnal rhythm is an example. But what internal or external events have a 90-minute cycle? No one knows, but an absence of theory is not hampering for the many who are fascinated with unraveling empirical puzzles and do not need theory or want it. Nor is theory necessary in order to ask if a 90-minute cycle can account for some of the variability in performance on a job. (Jack A. Adams)

NEWS & NOTES

ELECTIONS TO FELLOWSHIP IN THE ROYAL SOCIETY

Among the 40 elected to Fellowship by the Royal Society on 16 March were the following: Prof. J.E. Baldwin - Prof. of Organic Chemistry, Massachusetts Institute of Technology. For understanding chemical reactions and their application to synthesis of natural products; Prof. G.H. Dixon - Prof. in the Division of Medical Biochemistry at the Univ. of Calgary, Alberta, Canada. For the biochemistry of proteins; Dr. D.A. Ramsay - Principal Research Officer at the National Research Council of Canada, Ottawa. For contributions to molecular spectroscopy and molecular structure; Prof. A.I. Scott - Prof. of Chemistry, Texas A & M Univ. For his contributions to synthesis and biosynthesis of complex natural products; Prof. J.V. Smith - Prof. of Mineralogy and Crystallography at the Univ. of Chicago. For experimental and theoretical researches in crystallography, mineralogy, and petrology, and problems of ancient crustal rocks of the Earth, evolution of the Moon, and of chemical nature of the planets; Dr. J.H. Steele - Director of Woods Hole Oceanographic Inst., Massachusetts. For work on marine production and mathematical models for predicting primary production in nonsteady-state conditions; and Prof. E.W. Taylor- Prof. of Biophysics and Theoretical Biology, Univ. of Chicago. For researches on biological motile systems, and for isolating protein which forms microtubules, and for analyzing chemical events in muscle contractions.

INSTITUTE OF PHYSICS AWARDS

The Institute of Physics has made the following awards for 1978: Charles Vernon Boys Prize: jointly to Dr. R.A. Sherlock (Univ. of Waikato, Hamilton, NZ) and Professor A.F.G. Wyatt (Univ. of Exeter, UK) for their work on the propagation of phonons in liquid and solid helium.

Duddell Medal and Prize: to Professor E.G.S. Paige (Univ. of Oxford) for his contributions to the physical understanding, invention, and design of devices based on surface acoustic waves.

Glazebrook Medal and Prize: to Sir George Macfarlane, formerly of the Ministry of Defence, for his administration of governmental science and technology.

Guthrie Medal and Prize to Professor P.W. Anderson (Bell Laboratories, New Jersey) for his contributions to theoretical solid-state physics.

Maxwell Medal and Prize to Dr. M.V. Berry (Univ. of Bristol) for his contributions to theoretical physics in several fields.

Rutherford Medal and Prize to Professor P.T. Matthews (Univ. of Bath) for his contributions to elementary particle physics.

The Council of the Institute also elected the following as Honorary Fellows of the Institute: Sir Charles Frank, formerly Univ. of Bristol and Professor S. Chandrasekhar, Enrico Fermi Institute, Univ. of Chicago. The presentation of all these honors will be made in London at the Institute's Annual Dinner, 2 May 1978.

PROPOSED NATIONAL PROGRAMMING RESEARCH LABORATORY

According to *Computer Weekly* of 9 March 1978, a group of leading British computer scientists is proposing the establishment of a national programming research laboratory that could put Britain in the forefront of a new and important field of computer research. Professor David Barron (Southampton Univ.), Robert Hopgood (Brunel Univ. and also of the Rutherford Laboratory), Donald Michie (Univ. of Edinburgh), Michael Foster, (Royal Signals and Radar Establishment) and Dr. Horace Townsend, a consultant in clinical neuro-

physiology presented the proposal at a recent meeting at the Atomic Energy Research Establishment at Harwell. The first task of the new laboratory would be to study the newly discovered subject they call "knowledge refining." This consists of taking existing computerized problem-solving techniques and using them to improve the codifications of knowledge used by human experts in a wide range of specialized fields.

The process starts with a human expert feeding the machine with all pieces of advice he can think of about how he would tackle a specific problem. This advice is communicated in a special "advice language," usually in tabular form. The machine then analyzes all his rules in detail in interaction with him, correlating them, and considering a vast number of different situations and sequences of events. The end result is a codification of the rules that is much simpler and more consistent than the expert's original one. This output, again in the Advice Language, is translated back into English ready for use by human beings.

PERSONAL

Professor J.C. Bass has been reappointed as an honorary professor in the Department of Engineering at the Univ. of Warwick.

Mr. G.G. Bloodwoth, Reader in Electronics at the Univ. of Southampton, has been appointed to the Chair of Electronics and to the headship of the Department which is to be established in October.

Mr. D. Cardwell, Chief Scientist (Army) and Deputy Controller R&D Establishments and Research B (MOD) has been appointed Director of the Atomic Weapons Research Establishment, Aldermaston, in succession to Mr. W.J. Challens, who is retiring from the public service. Mr. I.H. Johnstone has been appointed to take up Cardwell's former position.

Manchester University has conferred the title of Emeritus Professor upon Jack Diamond, formerly Beyer Professor of Mechanical Engineering; Geoffrey Gee, formerly Professor of Chemistry; Henry Solomon Lipson, formerly Professor of Physics in the Faculty of Technology; George James Kynch, Professor of Mathematics in the Faculty of Technology; and Thomas Kenneth Ross, Professor of Corrosion Engineering in the Faculty of Technology.

Dr. G.F.J. Dutton, Reader in the Department of Biochemistry, has been appointed to a personal Chair of Pharmacological Biochemistry at the Univ. of Dundee.

Dr. B.D. Edwards, Director of Chloride Technical Ltd. and Director of Electric Vehicle Associates-Chloride, Cleveland, Ohio, has been appointed a special professor of the Department of Electrical and Electronic Engineering at the Univ. of Hull.

Dr. D.C. Ellwood, Head of the Biochemistry Section of the Microbiological Research Establishment, has been appointed to an honorary professorship in the Department of Environmental Sciences at the Univ. of Warwick.

Dr. M.S. Halliday, Lecturer in Experimental Psychology, Sussex Univ. has been appointed to the Chair of Psychology at the Univ. of Manchester in succession to Professor J. Cohen. In respect of his retirement, Cohen has had the title of Emeritus Professor conferred upon him by the University.

Sir Alan Hodgkin, Professor of Biophysics at the Univ. of Cambridge since 1970 and Chancellor of Leicester Univ., is to be Master of Trinity College, Cambridge, in succession to Lord Butler of Saffron Waldon, who retires in June. Sir Alan was President of the Royal Society from 1970 to 1975 and was joint winner of the Nobel Prize for medicine in 1963.

Professor David Thomas has been appointed to the Chair and headship of the Department of Geography in the University of Birmingham from 1 September. He has been head of the Department of Geography at St. David's University College, Lampeter, Wales.

OBITUARIES

Professor C.W. Davies, a distinguished electrochemist, died 1 March at the age of 82. He began his work in physical chemistry in 1923 with L.J. Hudleston at Aberystwyth on pure HF. Because this substance becomes contaminated by any contact with glass, all experimental work was done in homemade wax apparatus. These studies yielded accurate values for the transport

numbers of the various species. It was this work that led Davies to predict that the mobility values varied with the concentration. In 1928 he went to Battersea College of Technology where he soon built an active research school concerned with the very precise measurement of the conductivities of electrolytes in aqueous media, and the solubilities of sparingly soluble salts. In 1944 he was recalled to the Univ. of Wales at Aberystwyth to the Chair of Chemistry. Until his retirement in 1960, he continued his conductivity studies and also made important contributions to the understanding of ion-exchange resins, kinetics of crystal growth, and the effects of ion association in reaction kinetics. On his retirement, he returned to Battersea as Senior Research Fellow, leaving this post when the College became the Univ. of Surrey and moved to Guilford in 1969. Davies was the author of several books among which are *The Conductivity of Solutions* (1930) and *Ion Association* (1962).

Professor James Archibald Douglas, FGS, who was Professor of Geology at the University of Oxford from 1937 to 1950, died on 27 February at the age of 93. Prior to WWI, he carried out geological explorations in the Andes of Peru and Bolivia, the publication of the results of which led to his being awarded his doctorate. During World War I, he was twice wounded. Returning to Oxford, he became deeply interested in the geology of oil; he had an expert knowledge of the paleontology and stratigraphy of Persia and other Asiatic areas. He was elected to the Chair of Geology and Paleontology at Oxford in 1937. Much of his time was taken up in planning a new department, the opening of which was delayed by WWII. Finally in 1949, it was opened and now is a fitting memorial to his service to paleontology and geology in the University. He retired in 1950 and was made Professor Emeritus. He served on the Council of the Geological Society of London for an aggregate of nearly 20 years, was one of the honorary secretaries for 7 years, and for a time was a vice-president.

Professor Lajos Jánossy, Professor of Physics at Eötvös University, Budapest, died 2 March at the age of 66. In 1937 he joined P.M.S. Blackett at Birkbeck College in cosmic ray research. He followed Blackett to the Univ. of Manchester, and from 1938-47 was one of the leading members of the Manchester cosmic ray research group. He left to take up a senior professorship at the Dublin Institute of Advanced Study. He returned to Hungary in 1950 to play an important role in the academic and scientific development of that country. He was Director of the Central Research Institute for Physics from 1956-70 and represented Hungary on many international scientific bodies. He was a member of the Hungarian Academy of Sciences and was its Vice-President from 1958-73. Jánossy was known for his many scientific papers and books on cosmic rays, photons, relativity, and quantum mechanics, many of which have been translated from English into five other languages.

Professor J.W. McLeod, OBE, FRS, who died 11 March at the age of 91, was one of the pioneer bacteriologists of Great Britain. His outstanding work was on the diptheria bacillus, or *Corynebacterium diphtheriae* as it is now known. He was one of the authors of a classical report published in 1931 which first showed that the variability of the lethality of the causative micro-organism of diphtheria was due to different types of *C. diphtheriae* ranging in toxicity from the deadly *gravis* type to the relatively benign *mitis* type. He was also a pioneer in the investigation of bacterial oxidations, a subject on which he wrote in the Medical Research Council's *System of Bacteriology* (1931). In 1921, he was appointed Brotherton Professor of Bacteriology at Leeds University, and from 1948 to 1952, he was Dean of the Faculty of Medicine. After his retirement in 1952, he continued his active research with the Scottish Hospital Endowments Research Trust and later with Central Microbiological Laboratories in the Western General Hospital. He remained active in research until 1973.

ONRL REPORTS

R-14-77 PHOTOEMISSION ELECTRON MICROSCOPY: ANOTHER POWERFUL TOOL FOR THE MICROSCOPIST by A. Sosin

Photoemission Electron Microscopy, largely unknown in the United States, is an actively employed technique in several European laboratories. This report describes microscope design, image formation and contrast considerations, resolution and depth of information, and application. Photographs illustrate varying applications in metals, ceramics and semiconductors.

C-1-78 THE 45TH MEETING OF THE STRUCTURES AND MATERIALS PANEL OF THE ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT (AGARD) by I.M. Bernstein

The results of an AGARD meeting on nondestructive inspection techniques as well as a planning session on corrosion fatigue testing are reported. Designers and users of aircraft components and structures discussed the need for reliable crack detection procedures. The importance of both automated techniques and human inspection were emphasized. The corrosion fatigue program will serve as the topic for a future AGARD meeting.

C-2-78 QUANTUM-ELECTRONICS—A NATIONAL CONFERENCE AT SOUTHAMPTON by V.N. Smiley

At the University of Southampton, a National Conference on Quantum Electronics was held 14-16 September 1977. This is the third in a series of such conferences. The topics included laser theory, superfluorescence, laser applications to atomic and molecular physics, scattering pollution monitoring, nonlinear optics, isotope separation and biomedical applications. This report provides some general comments on the meeting as a whole and summarizes a few of the most interesting papers.

C-4-78 OPTICAL COMPUTING—A NATIONAL CONFERENCE AT VISEGRAD, HUNGARY by V.N. Smiley

The International Conference on Optical Computing in Research and Development was held in Visegrad, Hungary 4-9 October 1977. The fact that this field is in an early state of evolution was brought out by the speculative and preliminary nature of many papers. Hybrid systems combining digital or analog electronics and optical devices were emphasized in several papers and in a roundtable discussion. A factor slowing the development of such systems is that people from different disciplines are required to integrate their ideas. The main subjects discussed in the report are: laser graphic devices, holograms, hybrid image processing, and biological applications. In addition, some critical discussion of the general field of optical computing as well as some specific areas is included.

C-5-78 THE SECOND INTERNATIONAL CONFERENCE ON THE ELECTRONIC PROPERTIES OF 2-DIMENSIONAL SYSTEMS by B.D. McCombe

The Second International Conference on the Electronic Properties of Two Dimensional Systems, 19-22 September 1977, is reviewed critically. Topics discussed include: Space charge layers in Si MOS structures; carrier localization, electric field subband spectroscopy and many-body effects, dc and high frequency magneto-conductivity, cyclotron resonance, charge density waves, surface "superlattices"; electrons on liquid helium, bound state spectra and lifetimes, electron motion parallel to the surface, two dimensional plasmons, and Wigner crystallization; semiconductor superlattices; and other semiconductor MIS structures.

C-6-78 THE 13TH INTERNATIONAL SYMPOSIUM ON APPLIED MILITARY PSYCHOLOGY by M.J. Farr and C.R.J. Lafleur

The 13th International Symposium on Applied Military Psychology was hosted by Canada at the Canadian Forces Base, Lahr, Federal Republic of Germany, on 25-29 April 1977. There were 22 participants from 10 countries. The conference theme was the military in society. Four major topics were discussed: (1) military management and organization, (2) military personnel practices and problems, (3) attitudes toward the military, and change in those attitudes, and (4) the organization and programs of military psychology research units.

C-7-78 FIRST INTERNATIONAL CONFERENCE ON MATRIX ISOLATION SPECTROSCOPY by R.R. Smardzewski

This report disucsses the content of several papers presented at the First International Conference on Matrix Isolation Spectroscopy held on 21-24 June 1977 in West Berlin, FRG. A brief discussion of the technique of matrix isolation spectroscopy is included.